HAMILTON - WENTWORTH

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ESCARPMENT ACCESSIBILITY STUDY

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TECHNICAL REPORT

TOWN OF STONEY CREEK

McCORMICK RANKIN

HAMILTON – WENTWORTH

ESCARPMENT ACCESSIBILITY STUDY

TECHNICAL REPORT

TOWN OF STONEY CREEK

McCORMICK RANKIN

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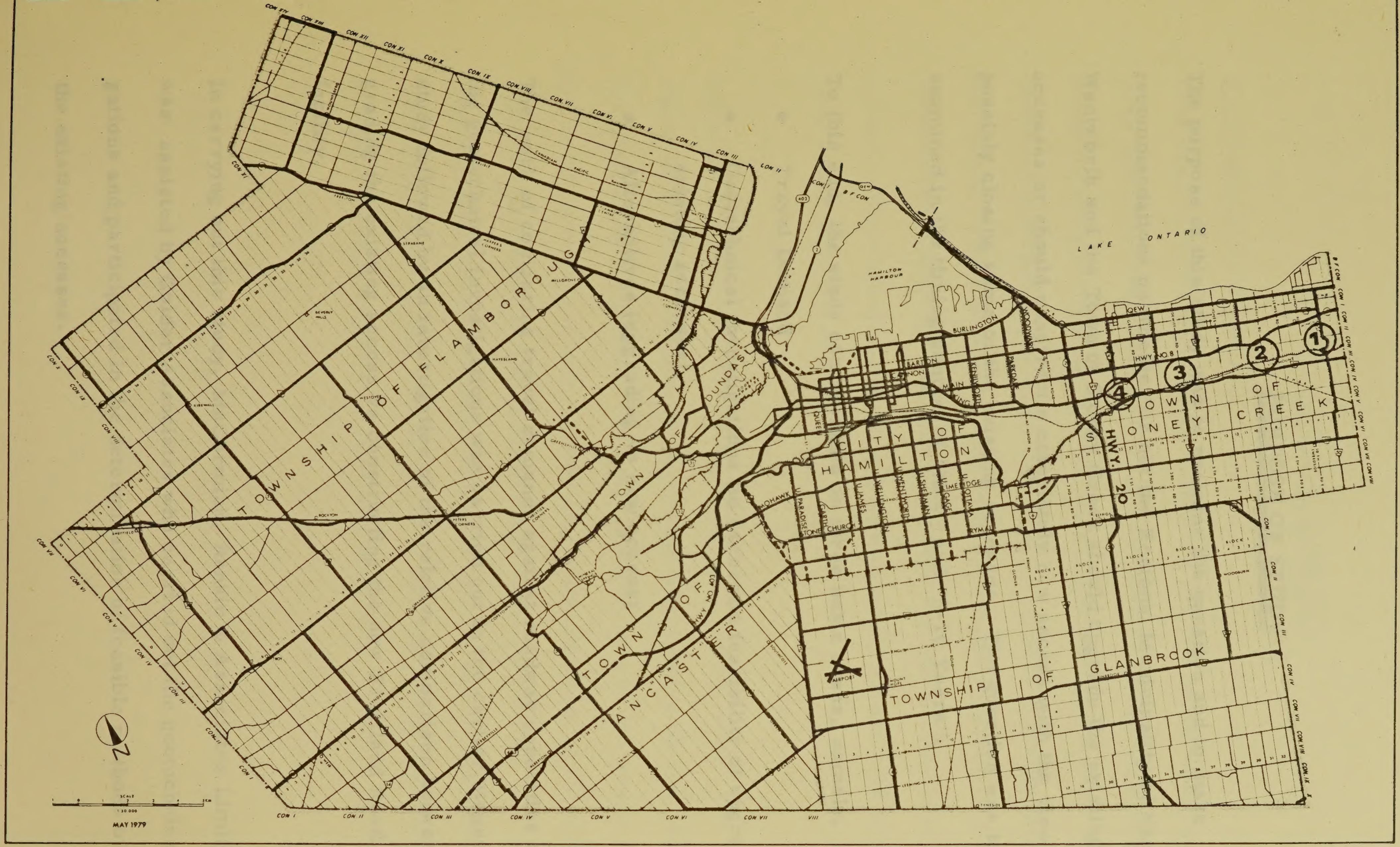
BACKGROUND

East of Highway 20 in the Town of Stoney Creek, there are currently four escarpment access roadways; Fifty Road, NcNeilly Road, De Witt Road and New Mountain Road. Each of these roadways is in generally poor condition. Over the years these roadways have come to the point where they no longer meet lane width, grade, and vertical and horizontal sight distance requirements. These roadways also have very high on-going maintenance costs, even to maintain them passible. All four accesses were constructed on side hill talus cuts and fills resulting in unstable foundation conditions.

The former County of Wentworth, the Town of Stoney Creek and more recently the Regional Municipality of Hamilton-Wentworth have looked at establishing a new Escarpment Access Road connecting Fruitland Road in the lower Town to Tapleytown Road above the escarpment. This project has not proceeded as a result of insufficient travel demands and high implementation costs. Official Plan amendments are, however, now proceeding and if implemented will permit development in the vicinity of the previously identified Fruitland Road Escarpment Access alignment.


LAKE ONTARIO
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TOWN OF DUNDAS
TOWN OF ANCASTER
CITY OF HAMILTON
TOWN OF STONEY CREEK
TOWNSHIP OF GLANBROOK
HWY. 20
HWY NO 8
QEW
AIRPORT
BURLINGTON
WOODWARD
PARKDALE
KENILWORTH
BARTON
CANNON
MAIN
QUEEN
U. JAMES
U. WELLINGTON
U. WENTWORTH
U. SHERMAN
U. GAGE
U. OTTAWA
LIMERIDGE
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GARTH
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LEGEND

	EXISTING	PROPOSED
INTER-REGIONAL HIGHWAY	▬	-----
ARTERIAL	▬	-----

① **FIFTY ROAD (REG. RD. 50)**
② **McNEILLY ROAD**
③ **DEWITT ROAD**
④ **NEW MOUNTAIN ROAD (REG. RD. 25)**

TRANSPORTATION

Planning & Development Department
Hamilton - Wentworth Region

Source : Map No. 3 Regional Official Plan

PLATE 1

PURPOSE OF STUDY

The purpose of this study was to examine the question and to make recommendations on whether or not the Regional Municipality of Hamilton-Wentworth and the Town of Stoney Creek should upgrade the existing accesses or should construct a completely new access with the view to possibly closing some of the existing accesses. The question was to be examined in the timing context of "Now" and "5-10 Years".

To this end, the study concentrated on three basic areas, namely,

- Travel Demand
- Geotechnical Investigations (to ascertain feasibility of upgrading existing accesses)
- Alternatives (upgrading vs new access)

The work of comparing travel demands against roadway capacities as well as the geotechnical investigations was carried out in the earlier stages of the study followed by an investigation of the relative comparison between upgrading the existing access vs constructing the new Fruitland Road access facility.

In carrying out this study, McCormick, Rankin & Associates Limited was assisted by Golder Associates who carried out the geotechnical investigations and participated in the determination of feasible methods of upgrading the existing accesses.

PURPOSE OF STUDY

The purpose of this study was to examine the question and to make recommendations on whether or not the Regional Municipality of Hamilton-Wentworth and the Town of Stoney Creek should upgrade the existing accesses or should construct a completely new access to the west to possibly closing some of the existing accesses. The question was to be examined in the design horizons of "Year 1" and "Plus 10 Years".

To this end, the study concentrated on three basic issues, namely,

- Travel Demand
- Geotechnical Investigations (to ascertain feasibility of upgrading existing accesses)
- Alternatives (upgrading vs new access)

The work of forecasting travel demand, accident (survey) expected as well as the geotechnical investigations was carried out in the earlier stages of the study followed by an investigation of the various connections between upgrading the existing accesses or constructing the new Centennial Road access facility.

In carrying out this study, McCormick, Rankin & Associates Limited was assisted by Golder Associates who carried out the geotechnical investigations and participated in the determination of feasible methods of upgrading the existing accesses.

EXISTING ACCESSES

FIFTY ROAD (Plates 11 & 15)

Fifty Road in the Town of Stoney Creek is a two lane north-south Regional Road extending from Mud Street (Regional Road 11) above the escarpment northerly to an interchange with the QEW below the escarpment. The escarpment section of the road is quite steep (up to 15% grades) and fairly narrow (8.7 metre platform width) with 7 substandard horizontal curves between Ridge Road and Highway 8, a distance of approximately 2.3 kilometers. The most recent road appraisal rated the escarpment section (No. 45020) at 51 out of 100.

McNEILLY ROAD (Plates 12 & 16)

McNeilly Road is a two lane north-south roadway under the jurisdiction of the Town of Stoney Creek. The escarpment section of the road is very steep (up to 20% grades) and quite narrow (8.2 metre platform width) with 2 substandard horizontal curves between Ridge Road and Highway 8, a distance of approximately 1.8 kilometers. The most recent road appraisal rated the escarpment section (No. 094) at 58 out of 100. Safe speed and structural adequacy were rated as being critically deficient.

DE WITT ROAD (Plates 13 & 17)

DeWitt Road is a north-south roadway extending from Ridge Road northerly to Lake Ontario and under the jurisdiction of the Town of Stoney Creek. The escarpment section of the road is very steep (up to 20% grades) and very narrow (4.9 metre platform width) consequently traffic flow is restricted to one lane southbound. There are 2 substandard horizontal curves between Ridge Road and Highway 8 a distance of approximately 1.6 kilometers. This roadway crosses the Welland Subdivision line of the Toronto, Hamilton & Buffalo Railway at grade in the vicinity of the base of the limestone strata which forms to top of the Niagara Escarpment. The existing daily rail traffic consists of 8 to 10 trains per day.

The most recent road appraisal rated the escarpment section (No. 112) at 38 out of 100 with surface width, safe speed and structural adequacy being critically deficient.

NEW MOUNTAIN ROAD (Plates 14 & 18)

New Mountain Road in the Town of Stoney Creek is a two lane north-south Regional Road extending from Ridge Road northerly to King Street. The escarpment section of the road is quite steep (up to 13.5% grades) and fairly narrow (8.5 metre platform width) with 1 substandard horizontal curve between Ridge Road and King Street, a distance of approximately 1.2 kilometers. This roadway underpasses the Welland Subdivision line of the

Toronto, Hamilton & Buffalo Railway immediately south of Leslie Drive. Vertical clearance at the grade separation is limited to 3-5 metres. The most recent road appraisal rated the escarpment section (No. 42510) at 57 out of 100.

TRAVEL DEMAND

TRAVEL DEMAND

TRAFFIC VOLUMES

Previous traffic counts on McNeilly Road and DeWitt Road dated back to 1975 and on Fifty Road and New Mountain Road to 1978, consequently the Region arranged for and subsequently supplied directional traffic counts (May 1980) for each of the four accesses at the crossing of the escarpment. This information is summarized as follows:

Fifty Road

	24 Hour Volume			Peak Hour Volume (p.m.)		
	SB	NB	Combined	SB	NB	Combined
Monday	439	471	910	54	28	82
Tuesday	439	568	907	67	47	114
Wednesday	444	478	922	56	36	92
Thursday	386	484	870	45	61	106
Friday	413	483	896	60	30	90

Average 24 Hour Volume 901
Peak Hour Volume 114

Since the 1978 AADT was approximately 930, it can be concluded that traffic on Fifty Road has remained fairly constant over the last 2 years.

McNeilly Road

	24 Hour Volume			Peak Hour Volume (p.m.)		
	SB	NB	Combined	SB	NB	Combined
Monday	394	462	856	48	34	82
Tuesday	391	413	804	47	31	78
Wednesday	391	474	865	32	23	55
Thursday	354	416	770	37	21	58
Friday	410	463	873	46	30	76

Average 24 Hour Volume 833
Peak Hour Volume 82

In 1975, the AADT on McNeilly Road was 575, consequently, traffic on this access has increased approximately 45% over the 5 years.

DeWitt Road

	24 Hour Volume			Peak Hour Volume (p.m.)		
	SB	NB	Combined	SB	NB	Combined
Monday	815			177		
Tuesday	816			154		
Wednesday	838			155		
Thursday	812			158		
Friday	854			168		

Average 24 Hour Volume	827
Peak Hour Volume	177

In 1975, the AADT on DeWitt Road was 1,025 or 500 in each direction as compared to 825 in 1980, an increase of approximately 65% over the 5 years.

New Mountain Road

	24 Hour Volume			Peak Hour Volume (p.m.)		
	SB	NB	Combined	SB	NB	Combined
Monday	1982	1932	3914	118	119	237
Tuesday	2033	1922	3955	106	122	228
Wednesday	1795	1924	3719	118	121	239
Thursday	1920	1814	3734	112	114	226
Friday	2291	2066	4357	244	156	400
Saturday	2119			117		
Sunday	1816			117		

Average 24 Hour Volume	3936
Peak Hour Volume	400

In 1978, the AADT on New Mountain Road at the crossing of the escarpment was 1,590 as compared to 3,940 in 1980, an increase of approximately 150% over 2 years.

ACCIDENT DATA

In addition to collecting data on traffic volumes on each of the four accesses, traffic accident data over a three year period between January 1, 1977 and December 31, 1979 was collected and subsequently analysed.

Over the three year period, there were a total of 48 accidents on the four accesses between Highway 8 and Ridge Road. The following summarizes the accident data by access road.

TABLE I

SUMMARY OF ACCIDENT DATA

(January 1, 1977 to December 31, 1979)

Access Road	Total Number Of Accidents	Total Number Of Personal Injuries
Fifty Road	12	7
McNeilly Road	9	1
DeWitt Road	2	0
New Mountain Road	25	12
Totals	48	20

The number of accidents are roughly proportional to the vehicle kilometers travelled on each roadway over the three year period with the exception of DeWitt Road, which because of the extremely poor service condition, has experienced fewer accidents as a result presumably of driver caution.

In addition, approximately one half of the total reported accidents occurred on wet or snow covered pavement and two thirds were located on the 'hill', sections characterized by steep grades.

The detailed accident data for each of the four access roadways is summarized in Appendix 'A'.

It can be concluded from a review of this information that the roadway geometry on each of the accesses is so deficient as to beneficially influence the driving habits of the average motorist.

POPULATION & EMPLOYMENT FORECASTS

Population and employment projections for the year 2001 have been developed by the Region of Hamilton-Wentworth, in consultation with the area municipalities and are summarized on Table 2. The Region is expected to grow an average growth rate of 1.2% to a population of 550,000 by the year 2001. Employment is expected to increase to a level of 290,000 jobs over the same period. Corresponding projections for the Town of Stoney Creek are as follows:

TABLE 2

POPULATION AND EMPLOYMENT DISTRIBUTION BY MUNICIPALITY

MUNICIPALITY	POPULATION					EMPLOYMENT	
	1961	1971	AVERAGE GROWTH RATE PER YEAR (1961-1971)	2001	AVERAGE GROWTH RATE PER YEAR (1971-2001)	1971	2001
Flamborough	18,200	21,000	1.5%	26,000	0.8%*	3,400	6,500
Dundas	12,900	18,600	4.4%	25,000	1.1%*	4,600	6,600
Ancaster	13,340	15,200	1.4%	23,000	1.7%*	2,000	7,400
Glanbrook	7,270	9,900	3.6%	14,600	1.6%	1,500	7,000
Stoney Creek	22,470	27,400	2.2%	75,400	5.8%	6,900	29.000
Hamilton	274,000	309,200	1.3%	386,000	0.8%	138,500	233,500
REGION	348,180	401,300	1.5%	550,000	1.2%	156,900	290,000

* Changes occured in municipal boundaries when Regional Government was formed.

Source : Table 2 – Regional Official Plan

TOWN OF STONEY CREEK

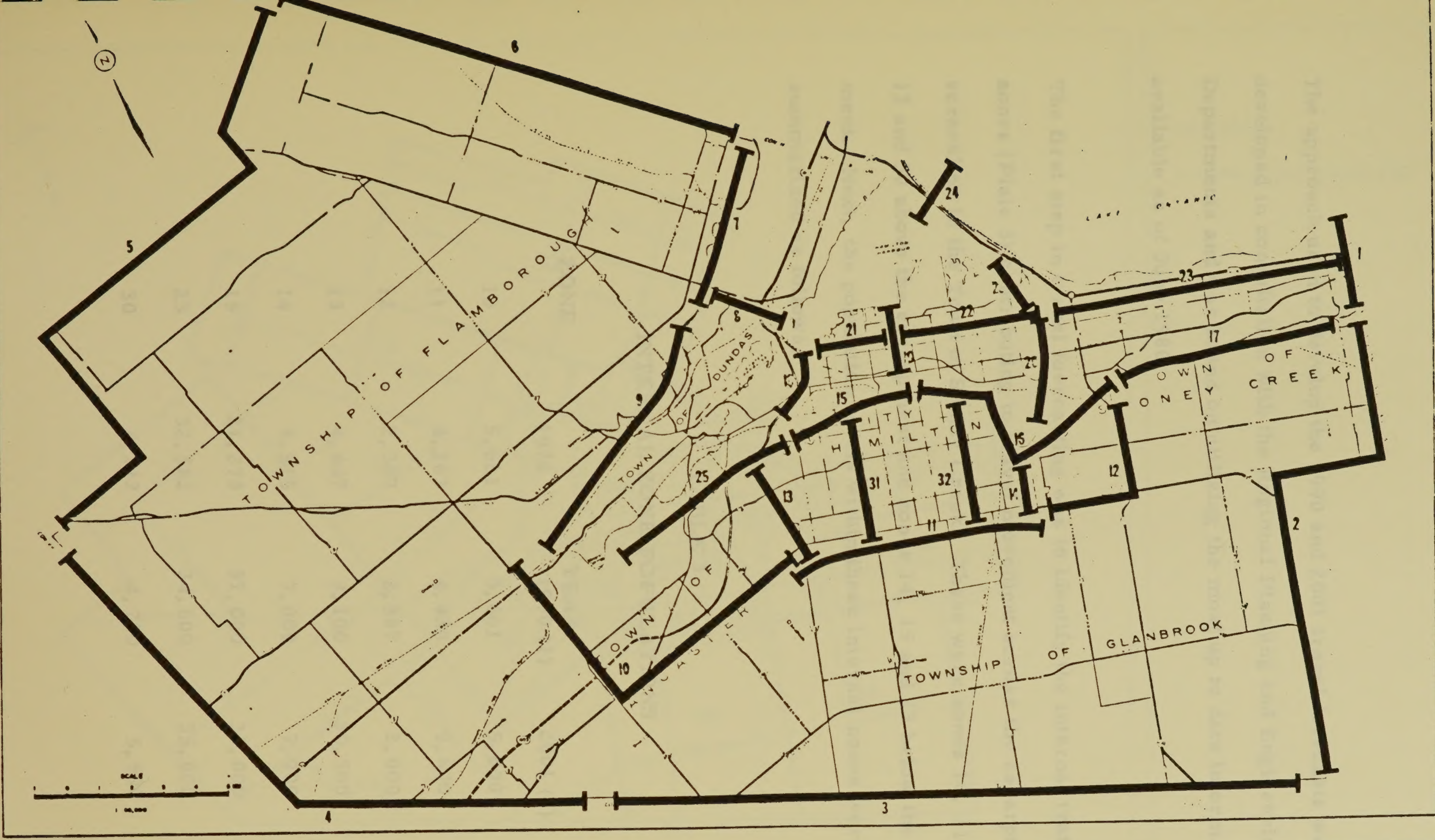
POPULATION & EMPLOYMENT PROJECTIONS

	1971	2001	% Change
Population	27,400	75,400	+275
Employment	6,900	29,000	+420

These projections represent vary significant increases within the Town of Stoney Creek as compared to the other five area municipalities comprising the Region of Hamilton-Wentworth. A review of the historical population data for Stoney Creek and the population forecast for the year 2001 indicates that the average annual growth rate is expected to increase from a growth rate of 2.3% per year over the last 10 years to 4.3% per year over the next 10 years.

TRAVEL FORECASTS

Basically, the methodology utilized in assessing travel demands across the escarpment in the Town of Stoney Creek was to compare the present roadway capacity of the four accesses, Fifty Road, McNeilly Road, DeWitt Road and New Mountain Road, with the 1980 observed volumes as well as the 1990 and 2001 predicted volumes, taking into account some diversion from Highway 20. The intermediate time frame to 1990 was considered necessary in the assessment as no significant increase in the capacity of the escarpment screenlines 16 and 17 (Plate 2) is contemplated until such time as the North-South Facility is constructed, which may take up to 10 years to implement.



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TOWNSHIP OF FLAMBOROUGH
TOWN OF DUNDAS
CITY OF HAMILTON
TOWN OF STONEY CREEK
TOWN OF ANCASTER
TOWNSHIP OF GLANBROOK
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LEGEND

NUMBER AND LOCATION OF SCREENLINES ⊢•⊣

Source : Transportation Capital Facilites Plan (Draft)

SCREENLINES

Planning & Development Department
Hamilton - Wentworth Region

PLATE 2

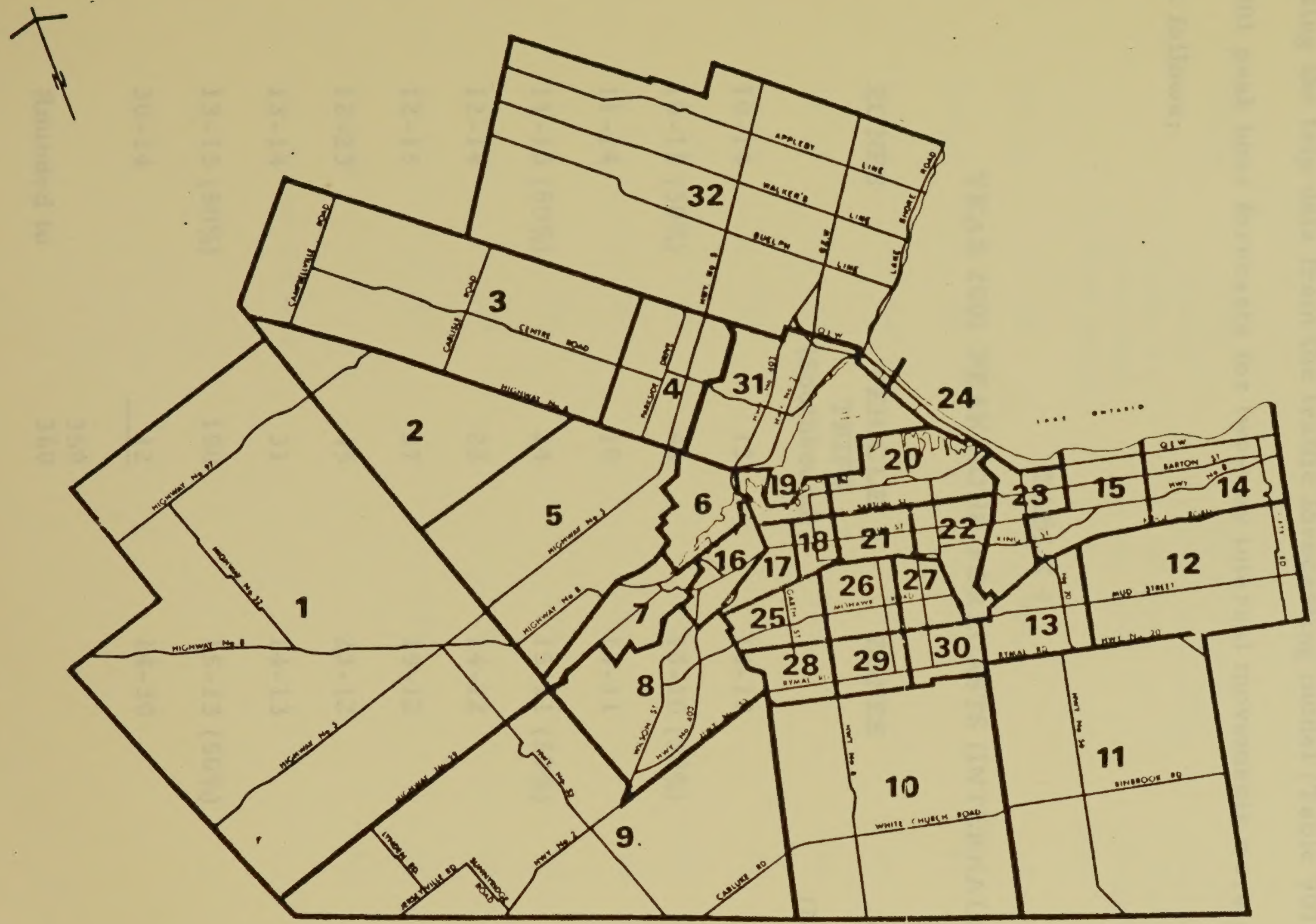
The approach used to develop the 1990 and 2001 travel forecasts was developed in consultation with the Regional Planning and Engineering Departments and was based on utilizing the most up to date information available as of June 1980.

The first step in travel forecasting was to identify the internal traffic zones (Plate 3) contributing to travel movement across the escarpment screenline in the Town of Stoney Creek. These were zones 10, 11, 12, 13 and 30 above the escarpment and zones 14, 15 and 23 below the escarpment. Next, the population levels within these internal zones were summarized as follows:

TABLE 3

INTERNAL ZONE POPULATIONS

ZONE	YEAR		
	1978	1990 (1)	2001 (2)
10	5,661	5,661	5,000
11	4,263	4,430	9,600
12	2,387	2,387	2,000
13	4,447	9,100	30,500
14	4,815	7,000	7,900
15	21,273	31,000	35,000
23	32,582	34,600	35,800
30	4,712	4,750	5,500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LAKE ONTARIO
APPLEBY LINE
WALKER'S LINE
GUELPH LINE
LAKE SHORE ROAD
Q.E.W.
CENTRE ROAD
CARLISLE ROAD
CAMPBELLVILLE ROAD
PARKSIDE DRIVE
HWY No 5
HWY No 403
HWY No 2
HIGHWAY No 6
HIGHWAY No 5
HIGHWAY No 8
HIGHWAY No 97
HIGHWAY No 52
HWY No 53
HWY No 2
HWY No 403
WILSON ST
LYNDEN RD
JERSEYVILLE RD
SUNNYBROOK ROAD
CARLUKE RD
WHITE CHURCH ROAD
HWY No 6
HWY No 56
BINBROOK RD
HWY No 20
MUD STREET
RYMAL RD
GARTH ST
MOHAWK ROAD
BARTON ST
KING ST
HWY No 8
Q.E.W.

LEGEND

ZONAL BOUNDARIES

INTERNAL MACRO TRAFFIC ZONES

Planning & Development Department
Hamilton - Wentworth Region

Nov. 1978

PLATE 3

(1) Interpolated from the Regional Population Growth Curves (1979-2001) developed by the Regional Planning Division.

(2) Allocated population by zone as determined by the Regional Planning Division in the preparation of the Region's Official Plan.

Using the trip data from the traffic forecasting model (Table 901) the year 2001 peak hour forecasts for two-way internal movements were summarized as follows:

TABLE 4

YEAR 2001 PEAK HOUR FORECASTS (INTERNAL)

ZONES	VEHICLE TRIPS (Southbound)	ZONES	VEHICLE TRIPS (Northbound)
10-14	13	14-10	12
10-15 (50%)	44	15-10 (50%)	16
11-14	10	14-11	44
11-15 (50%)	24	15-11 (50%)	43
12-14	23	14-12	35
12-15	57	15-12	42
12-23	45	23-12	40
13-14	31	14-13	144
13-15 (50%)	100	15-13 (50%)	156
30-14	12	14-30	15
	359		547
Rounded to	360		550

The 1990 peak hour forecasts for two-way internal movements were developed by factoring the year 2000 travel forecasts in direct proportion to the 1990 vs 2001 population level within each zone. This information is summarized as follows:

TABLE 5

YEAR 1990 ESTIMATED PEAK HOUR FORECASTS (INTERNAL)

Zones	2001 Vehicle Trips (1) (Two-Way Peak Hour)	Approximate Population Growth of Zone by 1990	1990 Vehicle Trips (Peak Hour) SB	NB
10-14	25	98%	12	13
10-15	60	92%	15	40
11-14	54	65%	28	7
11-15	67	79%	34	19
12-14	58	95%	33	22
12-15	99	90%	38	51
12-23	85	98%	39	44
13-14	176	37%	53	12
13-15	256	61%	95	61
30-14	27	88%	13	11
Totals			360	280

(1) From Table 4

Finally, using the origin/destination trip table, external vehicle movements from external zone 34 (Plate 4) to internal zones 14, 15, 20, 22 and 23 were assigned to Screenline 17 as follows:

TABLE 6

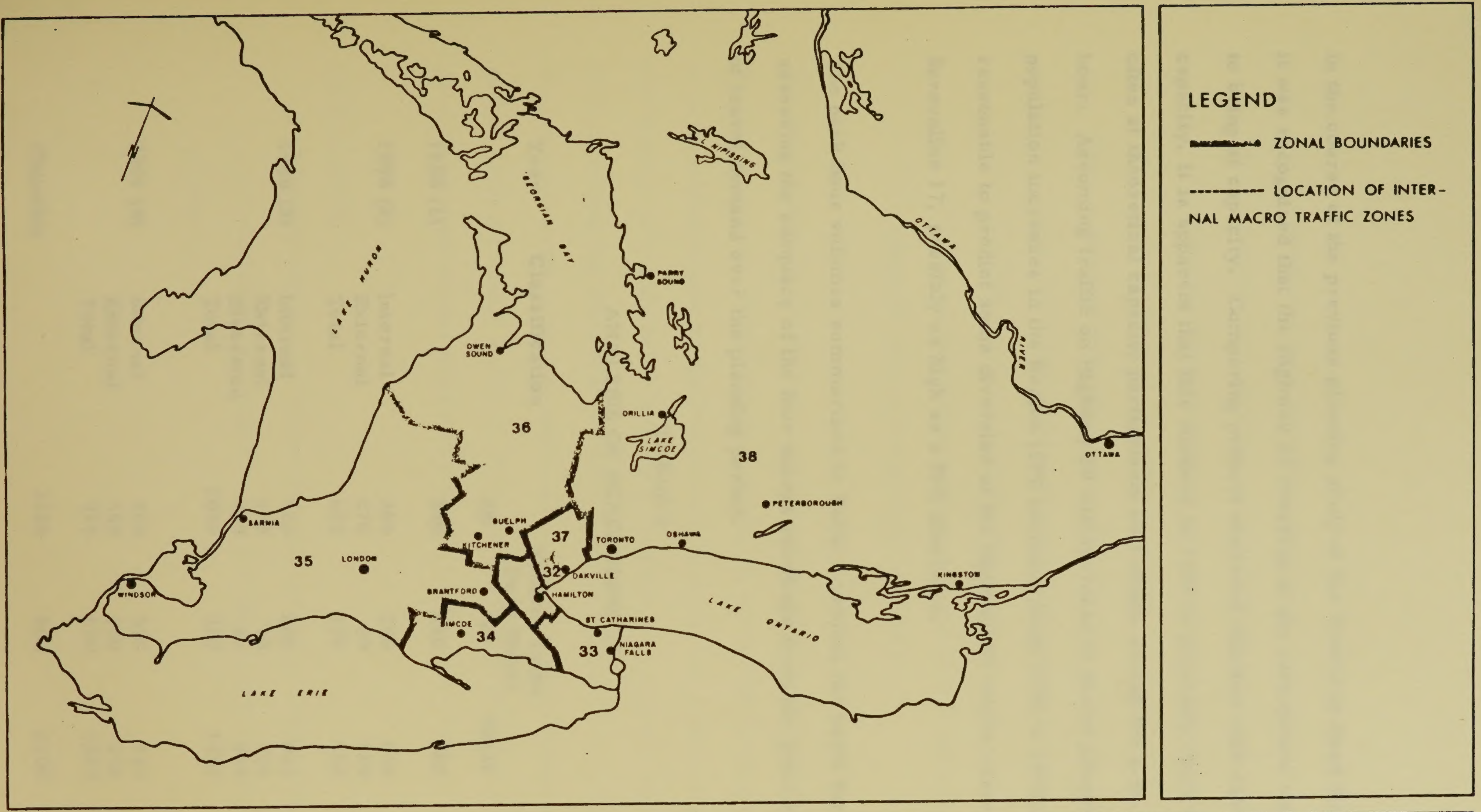
PEAK HOUR FORECASTS (EXTERNAL)

YEAR	VEHICLE TRIPS (Peak Hour)		
	SB	NB	Total
1990 (1)	270	50	320
2001	550	100	650

(1) Assumes 50% reduction in total 2001 external trip interchanges and 100% of zone 34 trips assigned to Screenline 17.

SCREENLINE ANALYSIS

Capacity calculations for the four access roadways crossing Screenline 17, based on surface widths of 6.5 metres, shoulder widths of 1 metre and gradients in excess of 15%, indicate that the peak hour capacity of the screenline is approximately 1200 southbound and 900 northbound. The difference is accounted for by the fact that DeWitt Road is restricted to one-way travel southbound only.



LEGEND
ZONAL BOUNDARIES
LOCATION OF INTERNAL MACRO TRAFFIC ZONES
LAKE HURON
GEORGIAN BAY
L. NIPISSING
OTTAWA RIVER
OTTAWA
PARRY SOUND
OWEN SOUND
ORILLIA
LAKE SIMCOE
PETERBOROUGH
KINGSTON
OSHAWA
TORONTO
OAKVILLE
HAMILTON
ST CATHARINES
NIAGARA FALLS
GUELPH
KITCHENER
BRANTFORD
SIMCOE
LONDON
SARNIA
WINDSOR
LAKE ONTARIO
LAKE ERIE
32
33
34
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36
37
38

EXTERNAL MACRO TRAFFIC ZONES

Planning & Development Department
Hamilton-Wentworth Region

Nov. 1978

PLATE 4

In the course of the previous planning study of the Fruitland Road Extension, it was recognized that the Highway 20 crossing of the escarpment was close to being at capacity. Comparing present observed volumes with calculated capacity, it is apparent that this roadway in 1980 is presently close to and often at theoretical capacity particularly on Fridays during the p.m. peak hour. Assuming traffic on Highway 20 will increase in direct proportion to population increases in the Region (50% increase from 1980 to 1990), it is reasonable to predict some diversion of the Highway 20 traffic easterly to Screenline 17, possibly as high as a 50% diversion.

The peak hour volumes summarized in Table 6 provide the basis for assessing the adequacy of the four access roadways from the point of view of travel demand over the planning period.

TABLE 6

ANALYSIS OF SCREENLINE 17

Year	Classification	Vehicle Trips (Peak Hour) SB	NB	Total	% Change from 1980
1980 (1)		540	240	780	
1990 (2)	Internal	360	280	640	
	External	270	50	320	
	Total	630	330	960	+ 24%
1990 (3)	Internal	360	280	640	
	External	270	50	320	
	Diversion	410	80	490	
	Total	1040	410	1450	+ 87%
2001 (4)	Internal	360	550	910	
	External	550	100	650	
	Total	910	650	1560	+102%
Capacity		1200	900	2100	

(1) Measured peak hour volumes.

(2) Assumes 50% reduction in total 2001 external trip interchanges, 100% of Zone 34 trips assigned to Screenline 17 and no diversion from Highway 20.

(3) Assumes 50% reduction in total 2001 external trip interchanges, 100% of Zone 34 trips assigned to Screenline 17 and 50% diversion from Highway 20.

(4) Assumes new North-South Facility west of Highway 20 with adequate feeder system in place by 1990.

The travel forecasts indicate an approximate doubling of traffic crossing the escarpment east of Highway 20. If the proposed North-South Facility is not constructed then traffic volumes will increase much more rapidly but will continue to remain below existing p.m. peak hour capacity well beyond 1990 (assuming the demand is distributed evenly across the screenline). Road improvements to provide additional capacity in the northbound direction may be necessary prior to 1990 if the North-South Facility is not constructed and a higher than normal amount of a.m. peak hour travel occurs.

CONCLUSIONS

- Travel forecasts, as summarized in Table 6, provide an adequate estimation of travel demand on this screenline over the planning period.

- The travel forecasts, when viewed in isolation, do not indicate the need for the construction of the Fruitland Road Extension, assuming an adequate distribution to specific roads across the screenline is maintained and the demand is distributed evenly across the screenline.
- The analysis of the screenline level of detail is not sensitive to localized impacts of traffic growth. An assignment of traffic to each link crossing the escarpment on Screenline 17 would help to identify roads where potential congestion problems may occur. If traffic growth on New Mountain Road continues at its present rate, it will reach capacity by the mid 1980's.

GEOTECHNICAL INVESTIGATIONS

GEOTECHNICAL INVESTIGATIONS

Golder Associates was retained to provide specialist geotechnical engineering services in connection with the Escarpment Accessibility Study being carried out for the Regional Municipality of Hamilton-Wentworth and the Town of Stoney Creek. The geotechnical aspects of the study included an assessment of the present stability and integrity of the existing escarpment accesses at Stoney Creek, and based on this assessment, the provision of geotechnical advice regarding alternative concepts for upgrading of the accesses, namely; Fifty Road, McNeilly Road, DeWitt Road and New Mountain Road.

INVESTIGATION PROCEDURE

The method of approach to the data collection phase of this study was as follows:

1) areas of potential slope and roadway instability on each of the four accesses were identified in the field and relevant topographic features including bedrock outcrop were mapped;
2) sampled boreholes were put down in areas identified as potentially unstable in order to gain an appreciation of subsurface conditions at these locations; and,
3) slope indicator casings were installed in the borings at critical areas along Fifty and McNeilly Roads in order to monitor potential slope movements.

Details of the field procedures followed and the results of the individual borings are given in Appendix 'B'.

GEOLOGY

The geology of this section of the Niagara Escarpment has been described in Golder's report to the Regional Municipality of Hamilton-Wentworth entitled "Hamilton-Wentworth Regional Soil Study" numbered 761008 and dated June, 1976.

The bedrock formations in the Region consist of gently tilted beds of sedimentary rocks of Paleozoic age underlain at a depth of about 600 m by crystalline basement rocks of Precambrian age. Because of regional tilting, the bedrock formations dip to the south and west at a slope of about 4 to 6 m per kilometre.

The bedrock within the escarpment consists of an alternating sequence of relatively hard and indurate dolomites, limestones and sandstones, and relatively softer and erodable shales. In the vicinity of the Stoney Creek escarpment accesses, these beds are relatively horizontal along the escarpment, but dipping to the south at a slope of about 5 degrees.

At the top of the escarpment is a stratum of relatively resistant dolomite. A second highly resistant layer of massive dolomite is present at all of the sites at elevations varying from 175 to 185 m; this massive dolomite bed is a marker bed which can be located at each of the sites and can be used to correlate stratigraphy between sites. The remaining strata in the escarpment are shales and sandstones which are susceptible to weathering and

erosion. It is postulated that the escarpment was formed by the preferential erosion of the less resistant shales and sandstones at the lower levels while the upper resistant dolomite eroded at a slower rate. Overburden deposits along the face of the escarpment consist of till and talus.

Inferred bedrock sequences have been superimposed on all cross sections shown in Appendix 'B'. The bedrock sequences have been compiled from previous work by Golder Associates, from the results of the current investigation, and from information published by the Geological Survey of Canada (Bolton, 1957).

SLOPE PROCESSES

Erosion, with consequent retrogression of the face of the escarpment, is a natural and continuing geological process. The process is one of degradation of exposed and near surface rock at the upper part of the slope, and accumulation of talus at the foot of the slope.

Upper Bedrock Slopes

The processes leading to degradation of rock are chemical alteration and disintegration. Chemical alteration takes place over geologic time spans and is relatively unimportant in the time scale of civil engineering works. Disintegration of the rock takes place due to: erosion by surface runoff and groundwater seepage; cyclic wetting and drying; and freezing and thawing. This results in softening, flaking and spalling of the shales (and sandstones), and the dislodged particles tumble or are washed down slope to form talus. The shale exposed. It is postulated that the escarpment was formed by the preferential erosion of the less resistant shales and sandstones at its foot, while the upper overlying dolomite eroded at a slower rate. Overburden deposits along the face of the escarpment consist of till and talus.

Inferred bedrock sequences have been superimposed on all cross sections shown in Appendix 'B'. The bedrock sequences have been compiled from previous work by Golder Associates, from the results of the current investigation, and from information published by the Geological Survey of Canada (Bolton, 1957).

SLOPE PROCESSES

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This process continues until the slope angle has been reduced to such a degree that dislodged fragments do not move down the slope but remain in place. At this stage soil and vegetation may develop on the slope. Examples of slopes which have reached this stage are the wooded slopes above the roadways along the upper parts of the Fifty Road and the McNeilly Road accesses.

Because such slopes were formed at the steepest angle that the products of degradation would remain in place, and not migrate downhill, they are in a marginally stable condition. The stability is enhanced by the root systems of the vegetation. Where the underlying rock is shale, however, further weathering and softening of the shale has probably occurred since the vegetation became established. Such slopes are therefore vulnerable to reactivation of surficial slope movements involving the fibrous root mat and the thin talus deposits (massive deep-seated landslides are unlikely because of the relatively shallow depth of bedrock).

layers within these more resistant rocks. The expansion of these clay seams within joints and fissures in the harder rocks loosens blocks of harder rock causing toppling of overhangs, cornices, flakes and pillars. The dislodged fragments tumble down the slope and become talus. This removal of rock from the face and accumulation of talus at the foot of the slope causes a gradual flattening of the angle of the slope.

This process continues until the slope angle has been reduced to such a degree that dislodged fragments do not move down the slope but remain in place. At this stage soil and vegetation may develop on the slope. Examples of slopes which have reached this stage are the wooded slopes above the roadways along the upper parts of the Filly Road and the McNally Road accesses.

Because such slopes were formed at the stable angle that the products of degradation would remain in place, and not creep downhill, they are in a marginally stable condition. The stability is enhanced by the root systems of the vegetation. Where the underlying rock is shale, however, further weathering and softening of the shale has probably occurred since the vegetation became established. Such slopes are therefore vulnerable to reactivation of surficial slope movements involving the fibrous root mat and the thin talus deposits (massive deep-seated landslides are unlikely because of the relatively shallow depth of bedrock).

Where construction involving cutting into the rock is necessary, a newly constructed slope may be stabilized in two ways. One way is to cut the slope to a relatively flat angle (such as 2 horizontal to 1 vertical), place topsoil, and establish vegetation as if the cutting were in overburden. The other method of stabilizing the slope is to cut the rock nearly vertically and to face the rock cut in some manner so as to retain the rock fragments in place. Where neither of these methods are considered warranted, then degradation of the rock face and generation of talus must be accepted. This may be satisfactory if an adequate "fall zone" is provided on the uphill side of the road where talus can accumulate until it is periodically removed. An example of this situation is the upper part of the New Mountain Road access.

Lower Talus Slopes

Talus is an accumulation, at the foot of a cliff, of dislodged rock fragments from the face of the cliff. Talus is normally only marginally stable because the fragments fall to a natural slope angle.

In the case of the Niagara escarpment, the source rocks are shale, dolomite and limestone with some sandstone layers. In general, the shale in the talus has completely disintegrated to clay, while the dolomite and limestone remain as recognizable rock fragments. The talus therefore generally consists of angular boulders of dolomite and limestone in an essentially clayey silt and sand matrix. Because of their nature of deposition (accumulation), these

talus slopes are, by definition, only marginally stable (factor of safety about unity). As a result, considerable straining or creep of the talus slopes occurs as further debris accumulates and as seasonal fluctuations in groundwater levels occur in the slopes. Because the depth to bedrock is significant, it is possible for relatively deep-seated, massive slope failures to occur in the talus.

Side hill road construction across the talus can therefore result in severe problems. Construction in cuts results in over-steepening of the slope above the road, construction on fill causes over-steepening and overloading of the slope below the road, and cut-and-fill construction over-steepens the slopes on both sides of the road. This over-steepening can induce excessive strain or creep type movement or outright instability. Although slope movement can be minimized by appropriate flattening of the slopes and/or permanent lowering of the groundwater level in the talus, elimination of the slope creep may be very difficult.

FIFTY ROAD

The Niagara escarpment is about 90 m in height at the location of the Fifty Road access. The crest of the escarpment is at about elevation 197 m and the foot is at about elevation 107 m. The relatively steep escarpment rise is interrupted by a gently sloping plateau between about elevation 135 m and elevation 155 m. Several houses are located on the plateau which, from a geotechnical viewpoint, effectively divides the access into an upper and a lower section.

Upper Fifty Road

A plan of the upper part of the Fifty Road access is shown on Figure 2, Appendix 'B'. In general, on the sidehill reach, above about elevation 165 m, the upper access traverses a wooded hillside with intermittently exposed bedrock above the roadway. The limestone/dolomite marker bed was intermittently visible at about elevation 185 on both the uphill and downhill sides of the road. Sandstone interbedded with clay seams was intermittently exposed between elevations 170 and 180. Surficial talus movement was apparent immediately adjacent to the uphill side of the roadway.

A total of three gullies are located on the uphill side of the roadway and were observed to carry appreciable water flows during spring run-off. These water flows have deeply incised the talus layer and exposed the underlying bedrock. On the banks of the gullies there is active erosion which has led to deposition of soil and organic materials in the ditches and culverts located along the roadway. In addition, exposure of the bedrock has led to undercutting and disintegration of the less resistant rock strata within these erosion channels. Below the roadway there were relatively fewer instances of active erosion along water channels.

The roadway structure, from a geotechnical viewpoint, appeared in generally good condition with exception of a section of roadway in the vicinity of Boreholes 1 and 3. This section of roadway, which is shown on Figure 2, is approximately 14 m long and extends from the centreline to the downhill

shoulder of the road. Tension cracks were visible at the centerline of the pavement towards the end of April, 1980 and correspond to significant movements recorded in the Borehole 3 slope indicator installation (refer to the Record of Borehole sheets). The vector addition of the maximum displacements indicates that the shoulder has moved horizontally approximately 55 mm between the taking of initial readings and April 30, 1980. The displacement profile suggests that the movements are of a surficial nature and restricted to the talus/fill overlying the bedrock at this location. The direction of the movement is coincident with the maximum downhill slope gradient.

Along the remainder of the access, only occasional relatively minor roadway slumping and pavement distress was noted at the locations shown on Figure 2. Displacements recorded on April 30, 1980 in the Borehole 2 slope indicator installation were relatively insignificant. Further, no visible roadway distress or downslope instability was evident in the immediate vicinity of Borehole 2 when the last set of readings was taken.

At the location of Boreholes 1 and 3, bedrock was encountered at about a depth of 2.6 m (elevation 178 m) and is overlain by fill and/or talus material. With the exception of a 0.3 m depth of loose sand and gravel at ground surface the fill/talus is predominantly soft to stiff clayey silt to silty clay with cobbles and boulders throughout. At Borehole 3 the underlying bedrock is a weathered sandstone with seams of clay to clayey silt.

shoulder of the road. Tension cracks were visible at the centerline of the pavement towards the end of April, 1980 and correspond to significant movements recorded in the Borehole 3 slope indicator installation (refer to the Record of Borehole sheets). The vector addition of the maximum displacements indicates that the shoulder has moved horizontally approximately 55 mm between the taking of initial readings and April 10, 1980. The displacement profile suggests that the movements are of a surficial nature and restricted to the talus/fill overlying the bedrock at this location. The direction of the movement is coincident with the maximum downhill slope gradient.

Along the remainder of the access, only occasional relatively minor roadway slumping and pavement distress was noted at the locations shown on Figure 2. Displacements recorded on April 30, 1980 in the Borehole 2 slope indicator installation were relatively insignificant. Further, no visible roadway distress or downslope instability was evident in the immediate vicinity of Borehole 2 when the last set of readings was taken.

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At the location of Borehole 2 a similar sequence of material was encountered with the exception that a deposit of stiff to very stiff clayey silt to silty clay soil is located from a depth of 3.0 to 4.7 m between the talus/fill materials and bedrock. The bedrock below elevation 170.7 m at this boring comprises interbedded weathered sandstone and shale.

Water level readings taken following completion of piezometer and slope indicator casing installations in Boreholes 1 and 3, respectively, indicate possible separate groundwater regimes at the fill/bedrock interface and within the bedrock. It is conceivable that fluctuations in the groundwater level at the fill/bedrock interface are related to the slope movement observed near Borehole 3.

Cross sections through the upper Fifty Road access at the approximate location of the boreholes are shown on Figures 4 and 5 in Appendix 'B'.

Lower Fifty Road

A plan of the lower part of the Fifty Road access is shown on Figure 3. This part of the access rises from about elevation 107 m to about elevation 140 m along a sidehill alignment. For most of this distance the roadway traverses the frontal slope of the escarpment, and along this section there are occasional deformations of the downhill road shoulder and some surficial sliding and erosion above the road.

The most serious stability problem appears to be adjacent to a water course which is actively undercutting the existing downhill slope of the roadway above about elevation 130 m. Borehole 4 was located in this area. The source of water for this erosion channel is a culvert which passes below Fifty Road just below Reservoir Road and discharges surface water run-off into the head of the gully. The resultant undercutting at the slope toe reaches a height of 1 m in places and appears to have accelerated the normally occurring surficial downslope movements. The surficial movements have been manifested at the roadway shoulder by horizontal guard post displacements of up to 1 m. In addition, there are longitudinal cracks at the edge of the pavement, together with obvious signs of shoulder slumping. The observed instability is confirmed by significant movements recorded at the slope indicator casing sealed into Borehole 4. The displacements recorded in this installation by April 30, 1980 show a maximum near-surface horizontal movement of about 14 mm. The shape of the displacement profile indicates that the downslope movements are generally within the surficial fill but that there may be movement at about elevation 127 m.

At the culvert location, roadway shoulder materials have been eroded and loss of roadway support is occurring.

The most serious stability problem appears to be adjacent to an erosion gully which is actively undercutting the existing downhill slope of the roadway above about elevation 130 m. Borehole 4 was located in this area. The source of water for this erosion channel is a culvert which passes below Tilly Road just below Reservoir Road and discharges surface water run-off into the head of the gully. The resultant undercutting of the slope has reached a height of 4 m in places and appears to have accelerated the normally occurring surficial downslope movements. The surficial movements have been manifested at the roadway shoulder by horizontal guard post displacements of up to 1 m. In addition, there are longitudinal cracks at the edge of the pavement located with obvious signs of shoulder slumping. The observed instability is confirmed by significant movements recorded at the slope indicator casing sealed into Borehole 4. The displacements recorded in this installation by April 30, 1980 show a maximum near-surface horizontal movement of about 18 mm. The shape of the displacement profile indicates that the downslope movements are generally within the surficial fill but that there may be movement at about elevation 127 m.

At the culvert location, roadway shoulder materials have been eroded and loss of roadway support is occurring.

At the location of Borehole 4, some 1.4 m of fill overlies hard clayey silt till which extends to a depth of about 15 m where it overlies shale. This indicates that the lower part of the Fifty Road access traverses a slope of relatively competent till material rather than the talus which often exists at the lower part of the escarpment. The water level in this boring corresponds approximately to the bottom of the erosion channel. A cross section through this part of the roadway and the water course is shown on Figure 6, Appendix 'B'.

McNEILLY ROAD

The McNeilly road site includes a relatively shallow plateau area between the escarpment toe and crest similar to that described for the Fifty Road site. The study at this site was restricted to the area above this plateau corresponding to the steepest portion of McNeilly Road between about stations 0+00 and 3+20 m (refer to Figure 7). Currently the condition of the McNeilly Road access appears in Appendix 'B', on a geotechnical basis, to be superior to the condition of the other three accesses.

As part of the geotechnical investigation at the McNeilly Road site, two boreholes (numbered 5 and 6) were put down at outside shoulder points along the access route. Slope indicator casings were installed in these borings to monitor potential slope movements at these locations. Cross sections at the locations of each of the slope indicator installations are shown on Figures 8 and 9.

The slope above McNeilly Road is characterized by a 2 to 3 m high cap of limestone/dolomite which is exposed along the major portion of the escarpment crest. The other major bedrock exposure on the uphill slope is the massive dolomite marker bed overlaying sandstone interbedded with weathered shale. This exposure is up to 4 m high and occurs between about stations 0+50 and 1+100. The dolomite bed passes beneath McNeilly Road at about station 0+43 and outcrops immediately west of station 0+00 on the slope below the roadway.

No visual signs of groundwater flow out of the rock exposures where observed at this site. With the exception of a water course at the extreme west end of the site, no erosion channels or gullies are present above or below the roadway. Some minor surficial sliding or talus material over intermittently exposed bedrock was noted above the roadway between about stations 0+00 and 0+60 m. Proceeding easterly, the uphill slope becomes progressively shallower and is terraced with intermittant rock outcrops. The slope is wooded and there is relatively little evidence of surficial movements.

Below the roadway, the slope is heavily wooded and rock outcrops are generally not visible below the dolomite marker bed. The only visual evidence of slope instability was seen immediately below Boreholes 6 and 6A. A cross section of this location is shown on Figure 8, Appendix 'B'. Based on aerial photography and site survey, the sloughing has taken place at a localized terraced area which is relatively denuded of mature trees and may indicate an area of

old slide debris or dumped fill (refer to cross section Figure 8). The slope indicator installation in Borehole 6 shows that between March 24, 1980 and April 30, 1980 there has been a total near-surface horizontal movement of about 25 mm (refer to Record of Borehole 6). Some settlement of the ground with respect to the slope indicator casing was also observed, but no visually apparent pavement cracking or other distress had developed by May 21, 1980. The shape of the displacement profile indicates that the movement is of a surficial nature and is restricted to the fill materials overlying till and bedrock.

At Boreholes 6 and 6A, a 2.6 m depth of predominantly granular fill overlies a thin deposit of silt till which in turn overlies sandstone bedrock at elevation 175.5 m. At Borehole 6 the sandstone was penetrated and overlies shale at elevation 174.1 m. A seepage zone was detected at the bottom of the fill and this seepage may have contributed to sloughing on the face of the slope which occurred at about the same elevation, as shown on Figure 8.

At Borehole 5 the fill deposit appeared more cohesive and shallower (1.2 m depth). Underlying the fill there is a 1.2 m depth of talus material overlying 4.6 m of silt till. The bedrock at this location was encountered at about elevation 164.4 m and generally progressed from a predominantly weathered shale to more competent limestone and dolomite with depth. A cross section at the location of Borehole 5 is shown on Figure 9, Appendix 'B'.

old slide debris or dumped fill (refer to cross section Figure 5). The slope indicator installation in Borehole 6 shows that between March 28, 1980 and April 30, 1980 there has been a total near-surface horizontal movement of about 25 mm (refer to Record of Borehole 6). Some settlement of the ground with respect to the slope indicator casing was also observed, but no readily apparent pavement cracking or other distress had developed by May 21, 1980. The shape of the displacement profile indicates that the movement is of a surficial nature and is restricted to the fill materials overlying till and bedrock.

At Boreholes 6 and 6A, a 2.0 m depth of predominantly granular fill overlies a thin deposit of silt till which in turn overlies sandstone bedrock at elevation 175.5 m. At Borehole 6 the sandstone was penetrated and overlies shale at elevation 174.1 m. A seepage zone was detected at the bottom of the fill and this seepage may have contributed to sloughing on the face of the slope, which occurred at about the same elevation, as shown on Figure 8.

At Borehole 5 the fill deposit appeared more cohesive and shallower (1.2 m depth). Underlying the fill there is a 0.6 m depth of stiff material overlying 4.6 m of silt till. The bedrock at this location was encountered at about elevation 161.6 m and generally progressed from a predominantly weathered shale to more competent limestone and dolomite with depth. A cross section at the location of Borehole 5 is shown on Figure 9, Appendix "B".

DeWITT ROAD

The DeWitt Road access has previously been investigated by Golder Associates. The results of the previous study were presented in a report entitled "Letter to the Corporation of the Town of Stoney Creek, Slope Stability Study, DeWitt Road, Stoney Creek, Ontario" numbered 751251 and dated June , 1976.

Prior to the earlier investigation, problems had developed in the section of the access above the existing railway track owned by the Toronto, Hamilton and Buffalo Railway Company. Several local rock falls from the rock cut above the road had occurred. In one area, the road had been reduced to only single lane width, the northern lane having been lost due to the failure in the slope below the roadway.

The 1975/76 investigation included detailing geological surface mapping of the slope above and below DeWitt Road together with a number of borings which were put down along the roadway to establish depths to bedrock. Possible remedial measures were reviewed at that time. One remedial measure considered consists, basically, of the removal of debris from the slope below the road and then flattening the overall slope by placing a substantial rock fill. It was recognized that the weight of the rockfill could have an adverse effect upon the stability of the railroad. This matter was not pursued at that time because the costs of such a scheme were well outside the limits of the existing budget restraints.

The present investigation therefore included two boreholes located along the railway right-of-way, in order to determine subsurface conditions beneath the railroad, so that the effect of the weight of the rockfill upon the stability of the railway could be assessed, together with supplementary inspection and mapping of the slope conditions during the spring of 1980.

A plan of DeWitt Road is shown on Figure 10, Appendix 'B' and cross sections of the escarpment above the railroad tracks are shown on Figures 11 to 13 inclusive. In order to facilitate discussion, the access has been divided into three sections, on the basis of the position of the roadway with respect to the massive dolomite marker bed.

Lower DeWitt Road

The lower section of DeWitt Road is considered to be the section where the elevation of the roadway is below the massive dolomite marker bed. This section is characterized by a steep rock cut above the road consisting of shaly limestone and interbedded sandstone and shales which are capped by the massive dolomite marker bed. A cross section near the east end of this section is shown on Figure 11.

Within this section, at a location approximately 30 m upgrade from the railroad crossing, there is a waterfall spilling over the escarpment. The waterfall empties into a large concrete culvert structure which in turn directs the water below DeWitt Road and the railway. In the area of the waterfall,

shales have been eroded resulting in undermining and reduced support to the more indurate overlying competent limestone and dolomite strata. At one location the massive dolomite and limestone beds are overhanding the less resistant shales by up to 1.5 m. A pattern of large vertical cracks associated with this overhang suggests that a large 18 m^3 block of dolomite and limestone may fall from the rock cut and possibly encroach upon DeWitt Road. Consequently this overhang should be scaled to minimize risk to traffic on DeWitt Road. A similar mechanisn has taken place within the last few years as shown by a large 4 m^3 block of dolomite presently lying on the road shoulder.

During the April, 1980 site reconnaissance, minor groundwater seepage was observed at several locations immediately above and below the dolomite stratum. However, the major source of visible water along the entire DeWitt Road alignment was due to surface water runoff flowing down the inside shoulder ditch. Along the lower DeWitt Road section, saturated talus material has accumulated to a depth of 3 m at the base of the rock cut. The primary sources of this material are the weathered shale underlying the dolomite bed and surficial talus material originating above the dolomite marker bed. It appeared at the time of this site reconnaissance (April, 1980) that the accumulated talus debris at the base of the rock cut had blocked the roadway ditch on the upslope side of DeWitt Road and had recently been cleaned out by maintenance crews.

The slopes below the lower portion of DeWitt Road are comprised of terraced slide debris which appears to be generally inactive and is covered by vegetation. However, some localized minor long-term creep of the saturated talus slope toe has taken place and led to visible encroachment into the railway embankment ditch.

Middle DeWitt Road

The middle section of DeWitt Road is considered to be the area where the dolomite marker bed passes below the roadway. It was in this area that the road width was reduced to a single lane prior to the 1975/76 investigation.

At about station 1+60 m, the massive dolomite bed which caps the rock cut on lower DeWitt Road passes beneath the roadway and appears on the downslope side. This intersection is marked by a perceptible reduction in the roadway gradient above the dolomite bedrock. The slope above DeWitt Road is characterized by continual surficial sliding of talus material over intermittently exposed bedrock. During the course of this current investigation heavy rainfall activated shallow talus slips which blocked the ditch and distributed debris as far as the centerline of the roadway.

Below the roadway, the retrogressive surficial sliding observed in April, 1980 was limited to the back scarp areas of older slide scars and controlled at the toe by a limestone layer which was exposed downslope from the marker bed. At approximately station 1+00 m the current mudsliding has extended to within

about 1 m of the DeWitt Road shoulder. Minor longitudinal cracking of the granular shoulder fill materials was also evident, but the pavement directly above the areas of instability did not appear to be distressed.

The area below the break point surveyed on the DeWitt Road downslope is covered by old slide debris which is highly saturated and over the long term slowly encroaching into the railway embankment ditch. The loose state and saturated condition of this talus material has also led to some minor mud sliding at the slope toe.

Upper DeWitt Road

Upper DeWitt Road corresponds to an area within about stations 0+00 and 1+00 m. The slopes below this upper sector are subdivided by the massive dolomite marker bed.

The upslope face of the escarpment comprises the same weak shale deposits which have been described for the middle sector, but these strata are less of a slide debris problem since the higher elevation of the road reduces the height of the exposed upslope face. The shale beds are capped by limestone beds at the escarpment crest, from which some groundwater seepage was noted. This seepage probably contributed to observed localized ravelling of this material.

From about station 0+70 to 1+00 m the pavement surface was observed to have suffered major distress in the form of cracking and rutting in the wheel path zones. However, this distress could not be associated with downslope sliding since the slopes below this portion of the roadway appear to be currently inactive and previous slide backscarps are more than 2 to 3 m from the north pavement edge. The pavement distress may be due to groundwater seepage in the roadway fill.

The talus slopes below DeWitt Road are covered with mature deciduous trees and broken by occasional vertical exposures of bedrock. Below the talus, the bedrock on these slopes appears to be close to the surface based on a continuous shallow exposure of bedrock, which can be observed in a water course located immediately west of the intersection of Ridge Road and DeWitt Road.

Railway Embankment

The slope above the railway appears to be subject to long term creep of talus debris into the railway ditch located on the south side of the railway embankment. The slopes below the railway were observed to range in height from 6 to 11 m at gradients up to 40° to the horizontal, and current or past slope instabilities were not evident at the time of this investigation. Talus debris consisting of rock slabs was observed on these slopes along with a mature growth of trees. Two water channels located at the east and west ends of the site were protected with rock slab walls and consequently it was

not possible to determine at this time the extent and composition of soil materials below these slopes (i.e. depths of talus and/or fill materials).

A total of three boreholes were put down along the south ditch of the railway at locations shown on Figure 10, Appendix 'B'. Similar subsurface conditions were determined at Boreholes 7 and 7A located below the middle sector of DeWitt Road, and Borehole 8 which was located below the lower sector. The borings revealed a variable depth of embankment fill below the ditch up to 1.3 m deep which is underlain by a generally very dense silt till material. The till overlies a 0.4 to 1.5 m thickness of very still silty clay. Bedrock was encountered at an average depth of 4.3 m (elevation 160.2 m) and consisted primarily of highly weathered laminated shale. However, based on resistance to auger advance, occasional harder rock layers, possibly sandstone and/or limestone, were encountered within the shale material and at borehole termination. Groundwater was observed close to ground surface in boring 7A in April, 1980 several weeks after completion of the drilling program. However, this high groundwater level could be due to surface water ponded within the ditch.

Results of Boreholes 7, 7A and 8 are summarized on Figures 11 and 12 and are shown in detail on the Record of Borehole sheets.

NEW MOUNTAIN ROAD

The upper part of the New Mountain Road access has had a history of instability. The upper part of the access was reconstructed and recessed into the escarpment in a rock cut during 1966. While the reconstruction appears to have achieved a stable roadway over much of the upper access, there have been continuing difficulties with pavement deformation and road shoulder instability along a section of the access about 50 m long beginning approximately at the culvert at the lower end of the rock cut section.

Two borings (Boreholes 9 and 10) were put down at the north shoulder of the road in the vicinity of the above culvert at the locations shown on Figure 14, Appendix 'B'. Cross section profiles at the locations of the borings are shown on Figures 15 and 16.

The rock cut section of the access extends from the intersection of New Mountain Road and Ridge Road to a point opposite Borehole 9. The rock cut gives a clear exposure of the escarpment bedrock sequence above about elevation 170 m.

As at the other three mountain accesses, there is a dominant massive dolomite marker bed within the exposed rock sequence. Below this indurate stratum the rock cut is near vertical but slopes back at about 30° to the horizontal above this bed. The major source of talus debris at the rock cut

appears to be due to disintegration of the limy shale beds which are exposed above the dolomite. The reconstructed rock cut includes a benched fall zone at the pavement level which is of sufficient width to prevent this debris from spilling onto the roadway.

West of the rock cut, the uphill slope is characterized by surficial sliding of talus material over intermittently exposed bedrock. At the time of the site reconnaissance carried out in April, 1980, the unlined ditch below these slopes was almost completely blocked with talus debris consisting of soil and organic materials.

A 600 mm diameter corregated steel culvert passes below New Mountain Road near the west end of the rock cut. This culvert is intended to carry water from an asphalt lined ditch below the rock cut to a drainage point on the downhill (north) slope of the roadway. On April 15, 1980, the upstream end of the culvert was blocked for at least 1 m with sand material accumulated from winter sanding operations. At that time, no visible water was entering the culvert at the intake end, but a flow of about 5 to 10 litres/minute was noted exiting from the downstream end of the culvert. Based on these observations it appears that the culvert is ruptured and is collecting groundwater from beneath the pavement. In the vicinity of the culvert there is an extensive area of pavement depression and cracking. It is possible that the poor condition of the culvert is contributing to this problem.

On the north slope of New Mountain Road no active slope instabilities were noted at the time of this field investigation.

Boreholes 9 and 10 revealed similar subsurface conditions in the vicinity of the distressed pavement. At both borings, approximately 3 m of predominantly granular fill overlies shales. Based on observed resistance to power augering the shale contains layers of harder rock and clay seams. Groundwater was encountered within the bedrock at both borings.

CONCLUSIONS

The geotechnical investigation has confirmed that each of the existing accesses is experiencing varying degrees of downhill movement due to slope creep. No active slope instabilities on any of the four accesses were noted at the time of the field investigations, however, there is always the possibility of sudden changes in embankment stability, particularly in the spring when groundwater conditions are worst. The obvious concern in this regard is the necessity to maintain traffic on DeWitt Road over the planning period or until such time as a new access is constructed in order to provide sufficient capacity across the screenline.

ALTERNATIVES

ALTERNATIVES

PRELIMINARY ASSESSMENT

In order to investigate the merits of upgrading the existing access roadways, it was necessary first to carry out a preliminary assessment of the four roadways from the point of view of what improvements might be practical and second to identify minimum standards to be utilized in the development of alternatives.

Following the review of the existing alignment and grade of each access roadway, it was quite apparent that any improvements to these roadways would have to be restricted to easing the horizontal alignment to 20 metres in the 'switch-back' locations and to widening the roadways. The grades were found to be so steep that any attempt to flatten the grades to conform to the minimum standard of 12% for this class of roadway would result in the total realignment of the access roadways and this was considered to be unacceptable.

DESIGN CRITERIA

Recognizing the limitations imposed by the present alignment and cross section, it was agreed that any work associated with reconstruction of the existing access roadways, Fifty Road, McNeilly Road, DeWitt Road and New Mountain Road, should conform to the geometric standards summarized in Table 7.

TABLE 7

RECOMMENDED GEOMETRIC STANDARDS FOR UPGRADING EXISTING ACCESS ROADWAYS

	'A' STANDARDS (Without Fruitland Road Extension)	'B' STANDARDS (With Fruitland Road Extension)
Classification	UCU	RCU
Design Speed	25 kph	25 kph
Curvature	20 m (1)	20 m (1)
Gradient	12.20%	12.20%
Stopping Sight Distance Min.	45 m	45 m
Equivalent Vertical Curve (crest)	K = 4	K = 4
Equivalent Vertical Curve (Sag)	K = 8	K = 8
Pavement Width	8.5 m	7.3 m
Shoulder Width	0.6/2.5 m (2)	1.0 m
Right-of-Way Width	30 m	30 m

(1) minimum radius based on maximum superelevation rate of 0.08 m/m

(2) uphill shoulder width/downhill shoulder width

The 'A' standard proposes the reconstruction of the present access roadways utilizing curb and gutter with a 2.0 metre climbing lane adjacent to the 8.5 metre pavement section. Alternately, the 'B' standard would eliminate the climbing lane and curb and gutter excepting for the uphill widening in rock cut (with steel facing).

Following the identification of geometric standards, a series of typical cross sections was developed for each of the two standards covering the range of types of construction that would be encountered in reconstructing each access roadway. The typical cross sections are illustrated in Appendix 'C' and are summarized as follows:

A1/B1 - Earth Fill/Earth Cut

A2-B2 - Uphill Widening in Rock Cut (No Facing)

A3/B3 - Uphill Widening in Earth Cut (With Bin Wall)

A4/B4 - Uphill Widening in Rock Cut (With Steel Facing)

A5/B5 - Downhill Widening on Rock Fill

A6/B6 - Downhill Widening with Tieback Wall System

UPGRADING EXISTING ACCESSES

Initially it had been planned to make use of the existing topographic mapping, 1" = 40' on Fifty Road and 1" = 200' on the other access roadways, however, the accuracy of any investigations using the 1" = 200' topographic mapping was found to be far too unreliable. Furthermore, the time and budget allocated to the study did not facilitate obtaining additional topographic mapping at a larger scale. Consequently, the approach utilized in carrying out the necessary feasibility studies was as follows:

1) develop and prepare unit construction costs for 6 typical cross sections on Fifty Road (Plate 11) over the escarpment section utilizing the 1" = 40' topographic mapping augmented by field cross sections (Sections A-A, B-B and C-C correspond with the location of the geotechnical investigation carried out earlier this year).

2) develop and prepare unit construction costs for 5 typical cross sections on DeWitt Road (Plate 13) over the section between the THBR crossing and Ridge Road utilizing field cross sections supplied by the Town of Stoney Creek (Sections 4+00 and 5+50 correspond with the location of boreholes).

3) subdivide each roadway into lengths representing the type of construction that would likely be encountered in upgrading each route (i.e. 1550 metres of A1, 200 metres of A2, 310 metres of A3 and 240 metres of A4 in the case of Fifty Road).

4) develop preliminary cost estimates for upgrading each access roadway utilizing the unit construction costs for various types of construction as summarized in Appendix 'D'.

In carrying out the investigations associated with upgrading Fifty Road between Highway 8 and Ridge Road (Plate 11) the following conclusions were reached:

- Realignment in the vicinity of the top of the escarpment is predicated on providing a consistent minimum curvature of 50 metres over the entire route.
- Reconstruction over sidehill sections would best be achieved by widening in total either uphill or downhill. The partial uphill and downhill widening approach would involve additional costs.
- Reconstruction in the vicinity of 'DD' would best be achieved by widening uphill using the A3/B3 typical cross sections to minimize cutting into the existing sidehill. Alternately widening downhill although less costly ($575/m vs $1,175/m), would denude the downhill slope of vegetation. This approach has been assumed in developing costs for the reconstruction of the other access roads where widening in earth would be required.

- Reconstruction in the vicinity of Sections 'A-A' and 'B-B' could best be achieved by widening uphill using the A4/B4 typical cross sections. Alternately widening downhill using the A6/B6 typical cross sections was found to be roughly the same cost, however, the geotechnical information gathered to date is too limited to be confident of the evaluation of the depth to rock at the outside edge of the widened section. Further geotechnical investigations at the preliminary engineering stage could be considered in order to properly evaluate the merits of uphill vs downhill widening in rock cut/talus sections of the escarpment particularly along the upper sections of Fifty Road and McNeilly Road. Widening downhill would probably be more advantageous from the point of view of being able to maintain existing traffic during reconstruction.
- With careful attention, reconstruction of Fifty Road to either standard could be carried out without serious social or environmental impacts.

In carrying out the investigations associated with upgrading McNeilly Road between Highway 8 and Ridge Road (Plate 12), the following conclusions were reached:

- Realignment at the top of the escarpment is predicated on providing a consistent minimum curvature of 20 metres over the entire route. In this regard, the alignment constraint is the 'switch-back' halfway up the escarpment. Alternately at the top, the roadway could be realigned to the west of the 'parkette', although this improvement would involve the purchase of more farmland.

- Reconstruction over the entire route would best be achieved by widening uphill although the downhill option might be considered, at the preliminary design stage, over the upper section depending on the depth to rock at the outside edge of the shoulder. In no case should widening on earth or rock fill be considered as this type of construction would result in unnecessary environmental impacts.

In carrying out the investigations associated with upgrading DeWitt Road between Hilts Lane and Ridge Road (Plate 13), the following conclusions were reached:

- The present condition of the roadway over the upper section warrants immediate attention in regards to scaling back the existing rock face in order to minimize the possibility of falling rock contributing to an accident.
- Reconstruction between Hilts Lane and Ridge Road could only be achieved by widening uphill using the A3/B3 and A4/B4 typical cross sections. Initially, some consideration was given to widening downhill, however, Golder Associates has determined that the minimum downhill slope for stability would be in the order of 1.5 to 1 which could not be accommodated between the THBR tracks and the upper section of DeWitt Road.

- Ridge Road should be realigned southerly as shown on Plate 13 in order to provide an adequate intersection with DeWitt Road at the top of the escarpment. The actual alignment would be subject to negotiations with the affected property owners.

In carrying out the investigations associated with upgrading New Mountain Road between King Street and Ridge Road (Plate 14), the following conclusions were reached:

- The present subway structure at the THBR is rated as being deficient due to restricted clearances and furthermore the south approach to the structure is in need of improvement, consequently, any upgrading of New Mountain Road to minimum standards should include the construction of a new subway immediately to the west of the present structure.
- Reconstruction between the THBR and Ridge Road could only be achieved by widening uphill using the A3/B3 and A4/B4 typical cross sections. The present roadway was constructed partially on a downhill rock fill and it is considered inadvisable to widen this fill further.
- Ridge Road should be realigned in conjunction with improvements to New Mountain Road in order to provide an adequate intersection between the two roadways at the top of the escarpment. The actual alignment would be subject to negotiations with the affected property owners.

To this point in the investigation of alternatives, two basic standards were considered for upgrading the four access roadways. It was recognized that a third standard (referred to as Standard 'C') which would involve remedial work only on each of the existing accesses night also be considered. This approach would include such work as ditching, replacement of culverts and guiderail as required and pavement resurfacing, etc.

Preliminary cost estimates for upgrading each of the four escarpment access roads are summarized in the following table. A breakdown of the cost estimates for each roadway is included in Appendix 'E'.

TABLE 8

SUMMARY OF PRELIMINARY CONSTRUCTION COST ESTIMATES
(MILLIONS OF DOLLARS)

	'A' STANDARD Reconstruction Urban Section with Climbing Lane (No Fruitland Road Extension)	'B' STANDARD Reconstruction Rural Section Without Climbing Lane (With Fruitland Road Extension)	'C' STANDARD Remedial Work Only (With Fruitland Road Extension)
Fifty Road	1.50	0.95	0.15
McNeilly Road	1.35	0.85	0.10
DeWitt Road	1.25	closed	closed
New Mountain Road	1.70	1.30	0.15
TOTALS	5.80	3.10	0.40

FRUITLAND ROAD ACCESS

The extension of Fruitland Road from Highway 8 southerly to the Tapleytown Road above the Niagara Escarpment was studied in detail by the former Hamilton-Wentworth Suburban Roads Commission and these investigations were documented in a functional planning report prepared by McCormick, Rankin & Associates Limited. The study concluded that the extension of this roadway across the escarpment was essential to the residential and industrial growth in the Town of Stoney Creek and was physically feasible at a reasonable cost (2.0 million dollars in 1969, including an allowance of $460,000 for property acquisition).

More recently, the Region of Hamilton-Wentworth Engineering Department studied an alternate alignment for Fruitland Road between the Queen Elizabeth Way and Highway 8 and concluded that such an alignment offset to the east of the present Fruitland Road was preferable to the use of the present alignment. This latter investigation reconfirmed the feasibility of the earlier alignment proposal south of Highway 8.

Using the estimated quantities summarized in Table 9.1 of the previous functional planning report and up-to-date unit prices for the various items of work, an updated cost for the extension of Fruitland Road south of Highway 8 was developed (Appendix 'E').

The total cost of constructing Fruitland Road as a two lane facility with a climbing lane between Highway 8 and the Tapleytown Road south of Ridge Road, including an overhead structure at the crossing of the THBR, is 4.0 million dollars (excluding property). The additional cost to expand the roadway to four lanes with a climbing lane, in the future, would be 2.9 million dollars.

Alternately, the cost of tunneling the escarpment on the Line 'C' alignment previously identified at 5.0 million dollars has esculated to approximately 7.5 million dollars in 1980.

CONCLUSIONS

The following table summarizes the comparative costs of upgrading the existing access roads, Fifty Road, McNeilly Road, DeWitt Road and New Mountain Road vs constructing the Fruitland Road Extension in conjunction with either remedial work only or a reduced upgrading standard.

TABLE 9

SUMMARY OF PRELIMINARY CONSTRUCTION COST ESTIMATES ALL FACILITIES (MILLIONS OF DOLLARS)

	'A' STANDARD Reconstruction Urban Section with Climbing Lane (No Fruitland Road Extension)	'B' STANDARD Reconstruction Rural Section Without Climbing Lane (With Fruitland Road Extension)	'C' STANDARD Remedial Work Only (With Fruitland Road Extension)
Fifty Road	1.50	0.95	0.15
McNeilly Road	1.35	0.85	0.10
Fruitland Road	-	4.00	4.00
DeWitt Road	1.25	closed	closed
New Mountain Road	1.70	1.30	0.15
TOTALS	5.80	7.10	4.40

SUMMARY

SUMMARY

Referring to the summary of the analysis of Screenline 17, Table 6, page 15, it is apparent that the travel demand across the screenline will increase appreciably over the planning period and probably to a greater degree over the next 10 years, assuming no completion of the North-South Facility until approximately 1990 and significant diversion of traffic from Highway 20. The summary of peak hour volumes indicates that the capacity of the screenline can meet the anticipated travel demand, however, it is also quite apparent that certain facilities such as New Mountain Road are likely to experience congestion problems as early as the mid 1980's. It is also important to realize that any upgrading of the existing access will not result in any appreciable increase in the capacity of the screenline as the existing grades of 12 to 20% would not be improved. Alternately, constructing the Fruitland Road Extension as a two lane access with a maximum gradient of 7% and a climbing lane would approximately double the capacity of the escarpment screenline, thus relieving the pressure on the other accesses as well as providing an alternate access across the escarpment.

The geotechnical investigation has confirmed that each of the existing accesses is experiencing varying degrees of downhill movement due to slope creep. No active slope instabilities on any of the four accesses were noted at the time of the field investigations, however, there is always the possibility of sudden changes in embankment stability, particularly in the spring when groundwater conditions are worst. The obvious concern in this regard is the necessity to

maintain traffic on DeWitt Road over the planning period or until such time as a new access is constructed in order to provide sufficient capacity across the screenline.

From Table 9, it can also be concluded that the cost of constructing a completely new access together with remedial work on the existing accesses (4.40 million dollars) is considerably less than the cost of upgrading the existing accesses to what can be regarded as minimum standards (5.80 million dollars).

In summary, construction of the Fruitland Road Extension between Highway 8 and the Tapleytown Road south of Ridge Road would best meet the Region's and the Town's objectives of improving the escarpment accessibility in the Town of Stoney Creek, taking into consideration the economic, social and environmental implications.

APPENDIX ‘A’ ACCIDENT DATA

ESCARPMENT ACCESSIBILITY STUDY

SUMMARY OF ACCIDENT DATA (JAN. 1/77 TO DEC. 31/79)

Access	Total	Pavement Condition		Grade		Combination	Injury/Fatality
		Dry	Wet	Level	Steep		
Fifty Road	12	8	4	4	7	1	7/0
McNeilly Road	9	4	5	3	6	-	1/0
Dewitt Road	2	1	1	-	2	-	0/0
New Mountain Road	25	11	14	6	15	4	12/0
TOTAL	48	24	24	13	30	5	20/0

ESCARPMENT ACCESSIBILITY STUDY

ACCIDENT DATA - FIFTY ROAD

	Location	Date	Pavement Condition	Road Alignment	Impact	Injuries/Fatality	Property Damage
1)	53' N. of Ridge Rd.	Dec. 12, 1977	LS Snow	St. /Level St. /Level	Sideswipe	0/0	$ 500
2)	On Ridge Rd.	Mar. 19, 1977	Dry	St. /Hill St. /Level	Angle	3/0	$1,700
3)	154' S. of Hwy. 8	Nov. 29, 1977	Dry	St. /Level	Angle	0/0	$ 900
4)	322' S. of Hwy. 8	Apr. 14, 1978	Dry	St. /Level	Rear End	0/0	$ 800
5)	966' S. of Hwy. 8	Mar. 7, 1977	Dry	Curve/Hill	Approach	0/0	$ 250
6)	1,048' S. of Hwy. 8	Nov. 11, 1978	Dry	Curve/Hill	Angle	0/0	$2,000
7)	1,440' S. of Hwy. 8	June 19, 1979	Dry	Curve/Hill	Approach	0/0	$3,000
8)	1,609' S. of Hwy. 8	May 4, 1977	Wet	St. /Hill	Other	1/0	$1,150
9)	1,609' S. of Hwy. 8	Nov. 4, 1977	Dry	Curve/Hill Curve/Hill	Approach	2/0	$1,000
10)	322' N. of Ridge Rd.	Feb. 11, 1979	LS Snow	St. /Hill St. /Hill	Rear End	0/0	$1,150
11)	274' N. of Ridge Rd.	Oct. 14, 1979	Dry	St. /Hill St. /Hill	Other	0/0	$1,200
12)	137' N. of Ridge Rd.	Dec. 7, 1977	Wet	Curve/Level Curve/Level	Sin M/V	1/0	$5,000

ESCARPMENT ACCESSIBILITY STUDY

ACCIDENT DATA - McNEILLY ROAD

	Location	Date	Pavement Condition	Road Alignment	Impact	Injuries/Fatality	Property Damage
1)	305' S. of Hwy. 8	May 17, 1977	Wet	St. / Level St. / Level	Angle	0/0	$1, 600
2)	322' S. of Hwy. 8	Dec. 1, 1979	Slush	St. / Level	Sin M/V	0/0	$ 450
3)	396' S. of Hwy. 8	May 22, 1979	Dry	Curve/Hill	Angle	0/0	$3, 200
4)	483' S. of Hwy. 8	Nov. 17, 1978	Wet	Curve/Hill	Sin M/V	0/0	$ 600
5)	518' S. of Hwy. 8	Oct. 13, 1977	Dry	Curve/Hill	Sin M/V	0/0	$2, 000
6)	549' S. of Hwy. 8	June 7, 1978	Wet	Curve/Hill Curve/Hill	Angle	1/0	$ 800
7)	644' S. of Hwy. 8	Jan. 1, 1979	Dry	Curve/Hill	Sin M/V	1/0	$1, 000
8)	805' S. of Hwy. 8	Dec. 9, 1978	Wet	Curve/Hill Curve/Hill	Approach	0/0	$ 425
9)	805' S. of Ridge Rd.	June 4, 1979	Dry	St. / Level	Sideswipe	0/0	$ 900

ESCARPMENT ACCESSIBILITY STUDY

ACCIDENT DATA - DEWITT ROAD

	Location	Date	Pavement Condition	Road Alignment	Impact	Injuries/Fatality	Property Damage
1)	483' N. of Ridge Rd.	Nov. 26, 1979	Dry	Curve/Hill	Approach	0/0	$2,000
2)	91' E. of Ridge Rd.	Feb. 5, 1979	Wet	St. /Hill	Other	0/0	$2,000

ESCARPMENT ACCESSIBILITY STUDY

ACCIDENT DATA - NEW MOUNTAIN ROAD

	Location	Date	Pavement Condition	Road Alignment	Impact	Injuries/Fatality	Property Damage
1)	12' W. Leslie Dr.	July 29, 1978	Dry	Curve/Hill	Sideswipe	0/0	$ 900
2)	On Leslie Dr.	Jan. 1, 1978	Wet	St. /Level		1/0	$2, 700
3)	18' S. Leslie Dr.	Nov. 21, 1977	Wet	Curve/Hill St. /Hill	Angle	0/0	$3, 300
4)	30' S. Leslie Dr.	Feb. 14, 1978	Dry	Curve/Hill Curve/Hill	Approach	0/0	$ 700
5)	61' S. of Leslie Dr.	May 28, 1977	Dry	Curve/Hill	Sin M/V	1/0	$ 250
6)	62' S. of Leslie Dr.	Nov. 20, 1977	Dry	Curve/Hill Curve/Hill	Approach	0/0	$1, 400
7)	68' S. of Leslie Dr.	June 6, 1977	Wet	Curve/Hill	Sideswipe	0/0	$2, 650
8)	69' S. of Leslie Dr.	Dec. 24, 1977	Wet Dry	Curve/Hill St. /Level	Angle	1/0	$1, 400
9)	76' S. of Leslie Dr.	Sept. 16, 1977	Wet Wet	Curve/Hill Curve/Hill	Approach	2/0	$1, 200
10)	91' S. of Leslie Dr.	Nov. 9, 1977	Wet Wet	St. /Hill St. /Hill	Angle	0/0	$ 675
11)	94' S. of Leslie Dr.	May 27, 1977	Dry	Curve/Hill	Sin M/V	2/0	$1, 500

	Location	Date	Pavement Condition	Road Alignment	Impact	Injuries/Fatality	Property Damage
12)	483' S. of Leslie Dr.	Mar. 25, 1978	Snow, Ice	St. /Level St. /Level	Rear End	0/0	$1,000
13)	61' S. of Loma Dr.	Nov. 28, 1977	Wet	Curve/Hill Curve/Hill	Rear End	2/0	$ 0
14)	84' S. of Loma Dr.	Oct. 6, 1977	Dry	Curve/Hill Curve/Hill	Sideswipe	1/0	$ 900
15)	122' S. of Loma Dr.	Apr. 3, 1978	Wet	St. /Level St. /Level	Sideswipe	0/0	$1,200
16)	322' W. on Ridge Rd.	Nov. 2, 1977	Wet Dry	St. /Hill St. /Level	Angle	0/0	$1,000
17)	91' W. of Ridge Rd.	Sept. 16, 1977	Wet	Curve/Hill	Angle	0/0	$ 750
18)	91' W. of Ridge Rd.	July 14, 1978	Dry	Curve/Hill	Turning	0/0	$ 800
19)	46' N. of Ridge Rd.	Oct. 17, 1979	Wet	Curve/Hill	Sin M/V	1/0	$2,300
20)	At Ridge Rd.	June 1, 1977	Dry	St. /Level St. /Level	Sideswipe	1/0	$2,300
21)	On Ridge Rd.	Sept. 28, 1977	Dry	Curve/Level St. /Level	Sin M/V	0/0	$ 700
22)	At Ridge Rd.	Feb. 5, 1978	LS Snow	Curve/Hill Curve/Hill	Sideswipe	0/0	$ 600
23)	At Ridge Rd.	Mar. 17, 1978	Dry	St. /Hill St. /Level	Sideswipe	0/0	$1,300

	Location	Date	Pavement Condition	Road Alignment	Impact	Injuries/Fatality	Property Damage
24)	On Ridge Rd.	Oct. 4, 1978	Dry	Curve/Level	Approach	0/0	$ 850
25)	91' S. of Loma Dr.	Apr. 3, 1978	Wet	St. /Level St. /Level	Sideswipe	0/0	$1,200

APPENDIX `B´ GEOTECHNICAL INVESTIGATIONS

LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

I. SAMPLE TYPES

AS	auger sample
CS	chunk sample
DO	drive open
DS	Denison type sample
FS	foil sample
RC	rock core
ST	slotted tube
TO	thin-walled, open
TP	thin-walled, piston
WS	wash sample

II. PENETRATION RESISTANCES

Dynamic Penetration Resistance: The number of blows by a 63.5 kg hammer dropped 760mm required to drive a 50mm diameter, 60 degree cone 0.3 m , where the cone is attached to 'A' size drill rods and casing is not used.

Standard Penetration Resistance, *N*: The number of blows by a 63.5 kg hammer dropped 760 mm required to drive a 50mmdrive open sampler

WH sampler advanced by static weight—weight, hammer

PH sampler advanced by pressure—pressure, hydraulic

PM sampler advanced by pressure—pressure, manual

III. SOIL DESCRIPTION

(a) *Cohesionless Soils*

Relative Density	*N*, *blows*/0.3 m
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) *Cohesive Soils*

Consistency	c_u, kPa
Very soft	Less than 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	over 200

IV. SOIL TESTS

C	consolidation test
H	hydrometer analysis
M	sieve analysis
MH	combined analysis, sieve and hydrometer[1]
Q	undrained triaxial[2]
R	consolidated undrained triaxial[2]
S	drained triaxial
U	unconfined compression
V	field vane test

NOTES:

[1] Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

[2] Undrained triaxial tests in which pore pressures are measured are shown as $\bar{Q}$ or $\bar{R}$.

LIST OF SYMBOLS

I. GENERAL

$\pi = 3.1416$

e = base of natural logarithms 2.7183

$\log_e a$ or $\ln a$, natural logarithm of a

$\log_{10} a$ or $\log a$, logarithm of a to base 10

t	time
g	acceleration due to gravity
V	volume
W	weight
M	moment
F	factor of safety

II. STRESS AND STRAIN

u	pore pressure
σ	normal stress
σ'	normal effective stress ($\bar{\sigma}$ is also used)
τ	shear stress
ϵ	linear strain
ϵ_{xy}	shear strain
ν	Poisson's ratio (μ is also used)
E	modulus of linear deformation (Young's modulus)
G	modulus of shear deformation
K	modulus of compressibility
η	coefficient of viscosity

III. SOIL PROPERTIES

(a) *Unit weight*

γ	unit weight of soil (bulk density)
γ_s	unit weight of solid particles
γ_w	unit weight of water
γ_d	unit dry weight of soil (dry density)
γ'	unit weight of submerged soil
G_s	specific gravity of solid particles $G_s = \gamma_s/\gamma_w$
e	void ratio
n	porosity
w	water content
S_r	degree of saturation

(b) *Consistency*

w_L	liquid limit
w_P	plastic limit
I_P	plasticity index
w_S	shrinkage limit
I_L	liquidity index $= (w - w_P)/I_P$
I_C	consistency index $= (w_L - w)/I_P$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
D_r	relative density $= (e_{max} - e)/(e_{max} - e_{min})$

(c) *Permeability*

h	hydraulic head or potential
q	rate of discharge
v	velocity of flow
i	hydraulic gradient
k	coefficient of permeability
j	seepage force per unit volume

(d) *Consolidation (one-dimensional)*

m_v	coefficient of volume change $= -\Delta e/(1+e)\Delta\sigma'$
C_c	compression index $= -\Delta e/\Delta \log_{10} \sigma'$
c_v	coefficient of consolidation
T_v	time factor $= c_v t/d^2$ (d, drainage path)
U	degree of consolidation

(e) *Shear strength*

τ_f	shear strength	
c'	effective cohesion intercept	in terms of effective stress $\tau_f = c' + \sigma' \tan \phi'$
ϕ'	effective angle of shearing resistance, or friction	
c_u	apparent cohesion*	in terms of total stress $\tau_f = c_u + \sigma \tan \phi_u$
ϕ_u	apparent angle of shearing resistance, or friction	
μ	coefficient of friction	
S_t	sensitivity	

---

*For the case of a saturated cohesive soil, $\phi_u = 0$ and the undrained shear strength $\tau_f = c_u$ is taken as half the undrained compressive strength.

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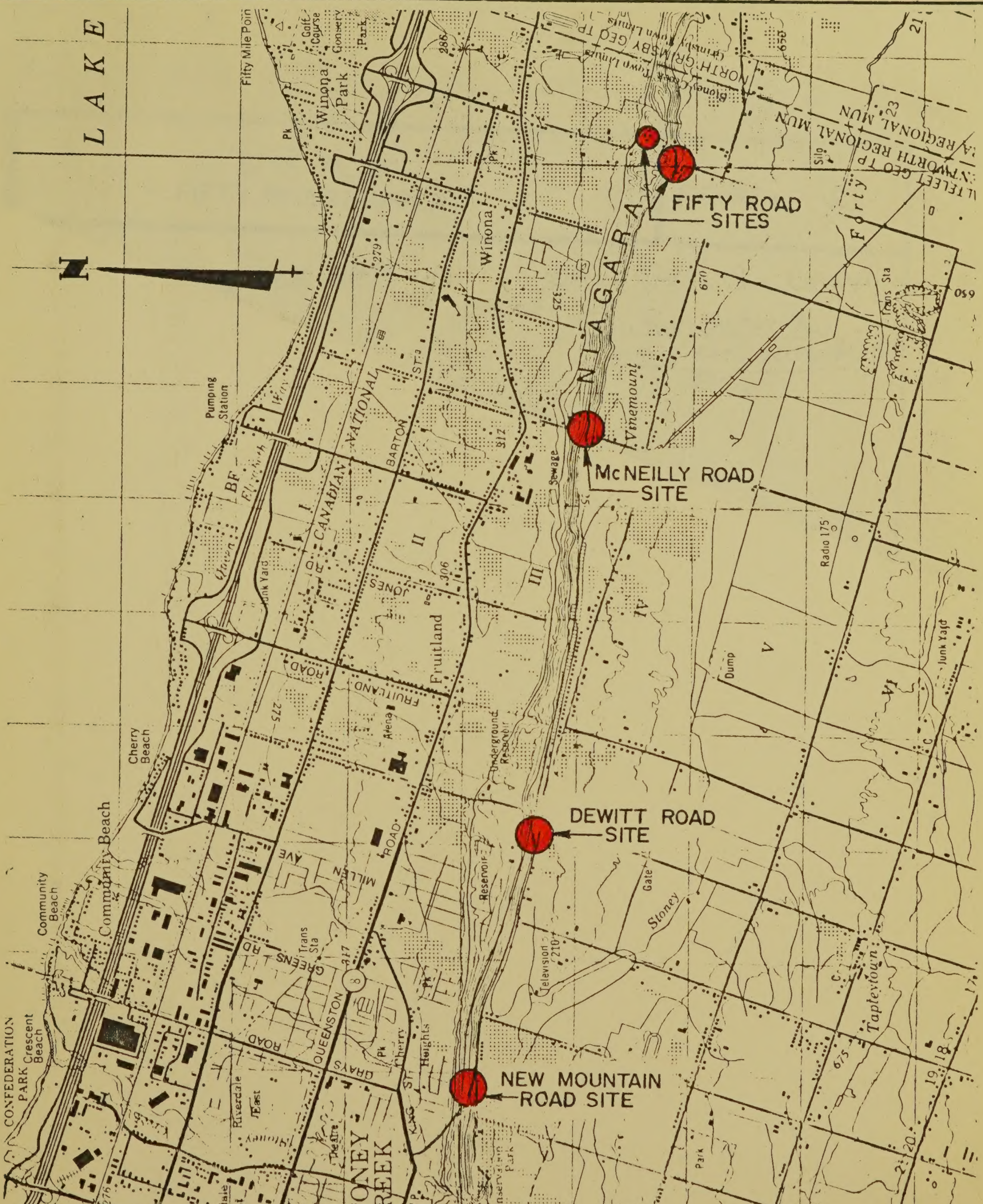
KEY PLAN

FIGURE 1


FIFTY ROAD SITES
McNEILLY ROAD SITE
DEWITT ROAD SITE
NEW MOUNTAIN ROAD SITE
LAKE
N
NIAGARA
Winona
Winona Park
Fifty Mile Point
Pumping Station
Cherry Beach
Community Beach
CONFEDERATION PARK
Crescent Beach
STONEY CREEK
QUEENSTON ROAD
GRAYS ROAD
GREENS RD
MILLEN AVE
FRUITLAND ROAD
JONES RD
BARTON ST
CANADIAN NATIONAL
Fruitland
Vinemount
Tapleytown
Forty
Stoney
Sewage
Underground Reservoir
Reservoir
Television
Radio
Dump
Junk Yard
Trans Sta
Arena
Conservation Park
NORTH GRIMSBY GEO TP
NIAGARA REGIONAL MUN
HAMILTON-WENTWORTH REGIONAL MUN
SALTFLEET GEO TP
II
III
IV
V
VI

SCALE - 1:50,000 (METRIC)

Date APRIL 1, 1980
Project No. 791-1362

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a Later Date.

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Library

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Library **http://www.hpl.ca**

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Insert to Be Photographed at
a Later Date.

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Library

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Material in Person, Please
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Library **http://www.hpl.ca**

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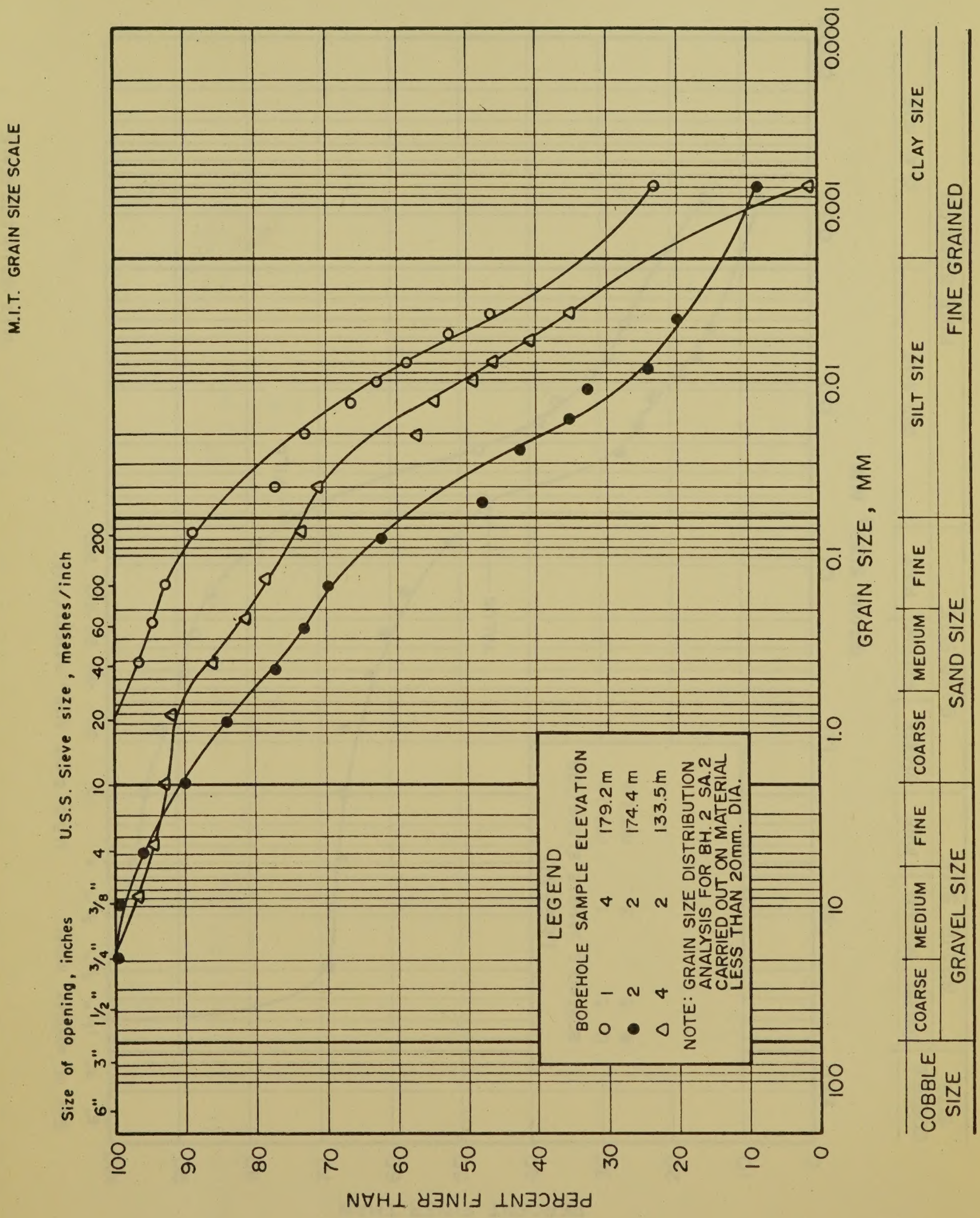
GRAIN SIZE DISTRIBUTION
FIFTY ROAD SITE TALUS / FILL MATERIAL

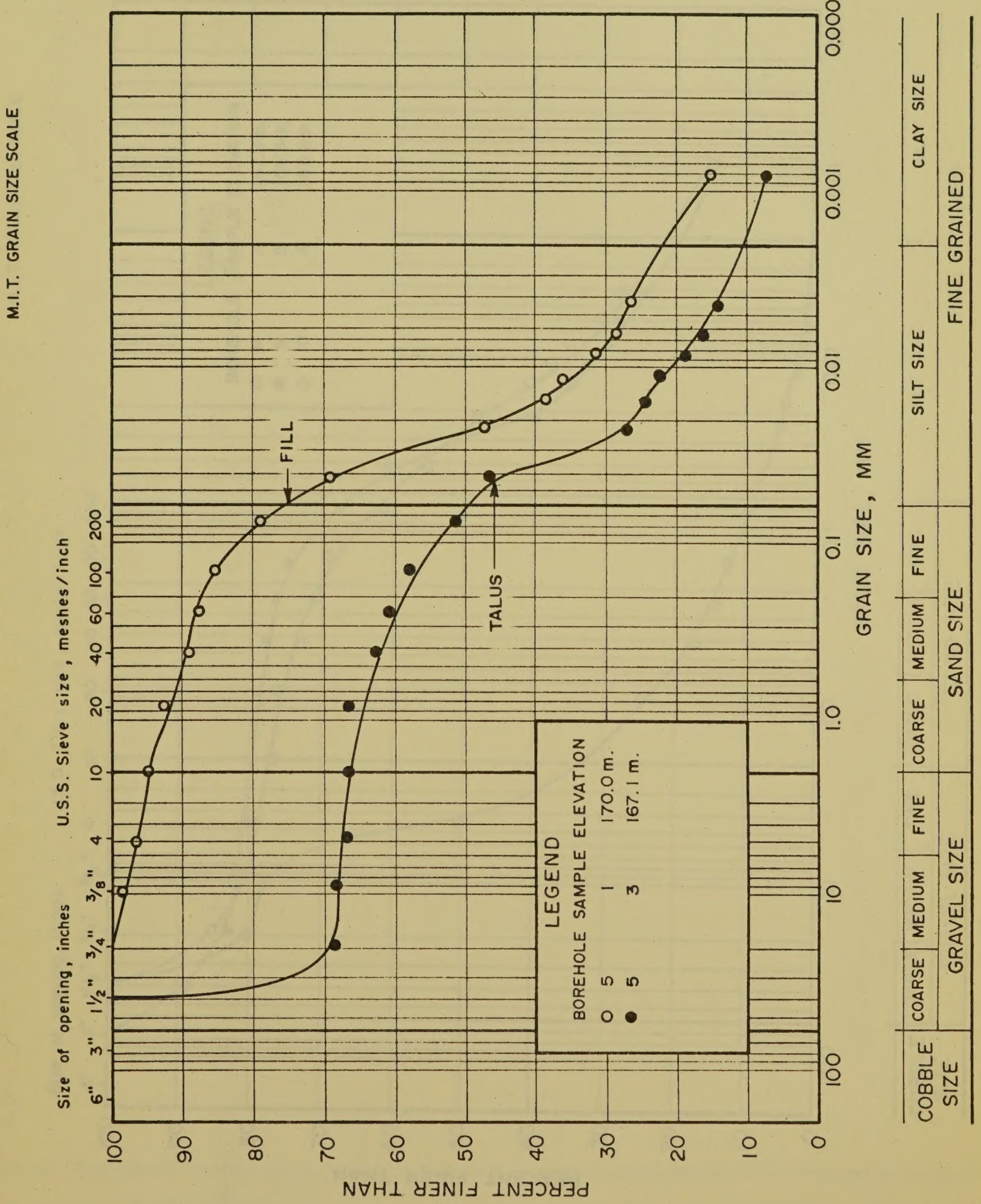
FIGURE 17



Golder Associates

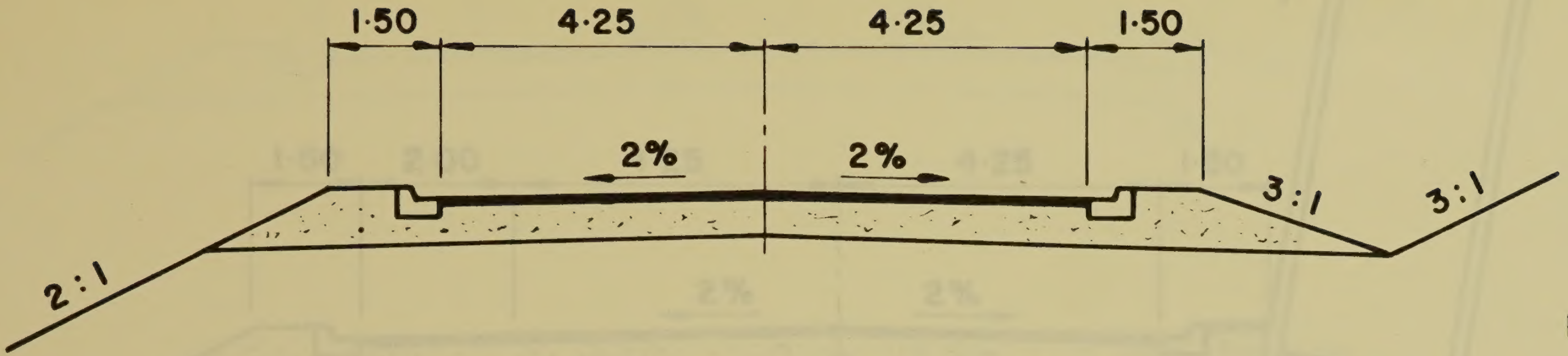
GRAIN SIZE DISTRIBUTION
McNEILLY ROAD SITE TALUS/FILL MATERIAL

FIGURE 18



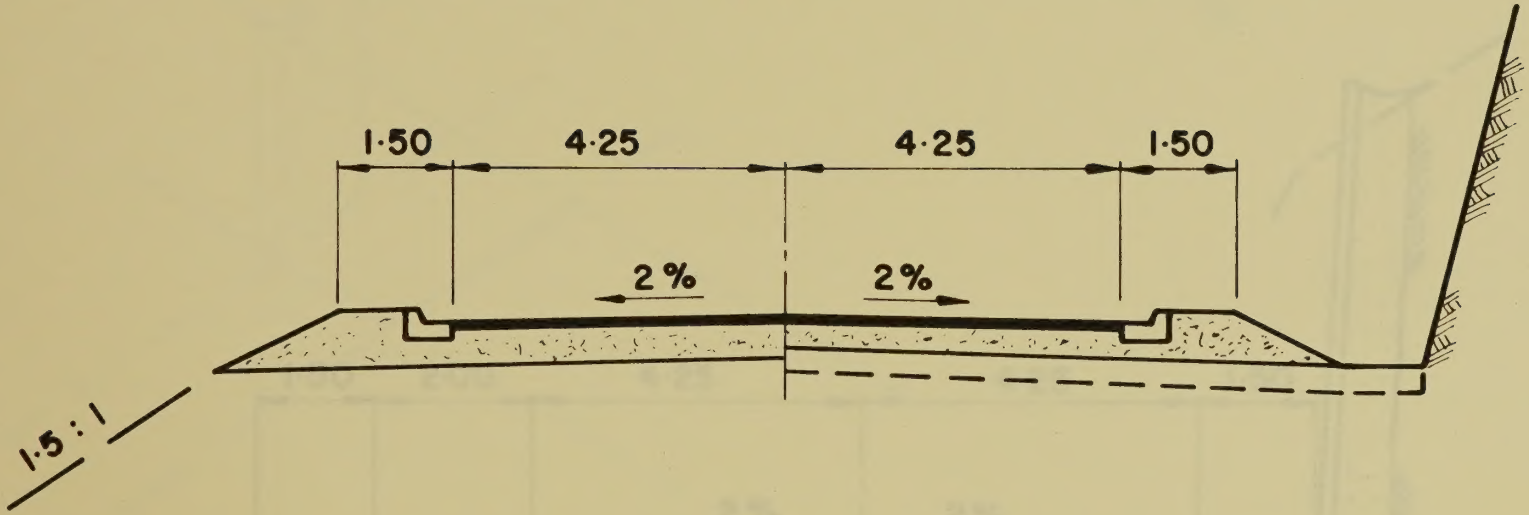
Golder Associates

APPENDIX `C´ TYPICAL CROSS SECTIONS


1·50
4·25
4·25
1·50
2%
2%
3:1
3:1
2:1

A1

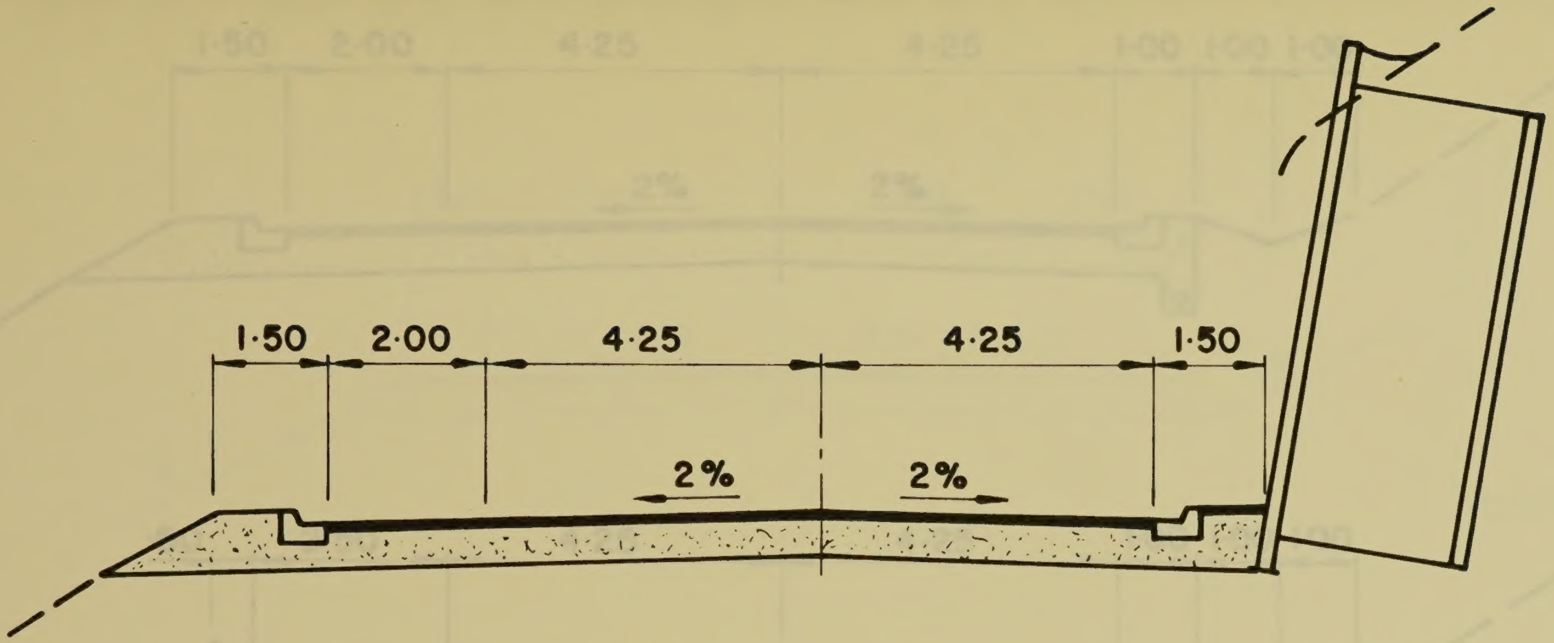
EARTH FILL / EARTH CUT


1·50
4·25
4·25
1·50
2%
2%
1·5:1

A2

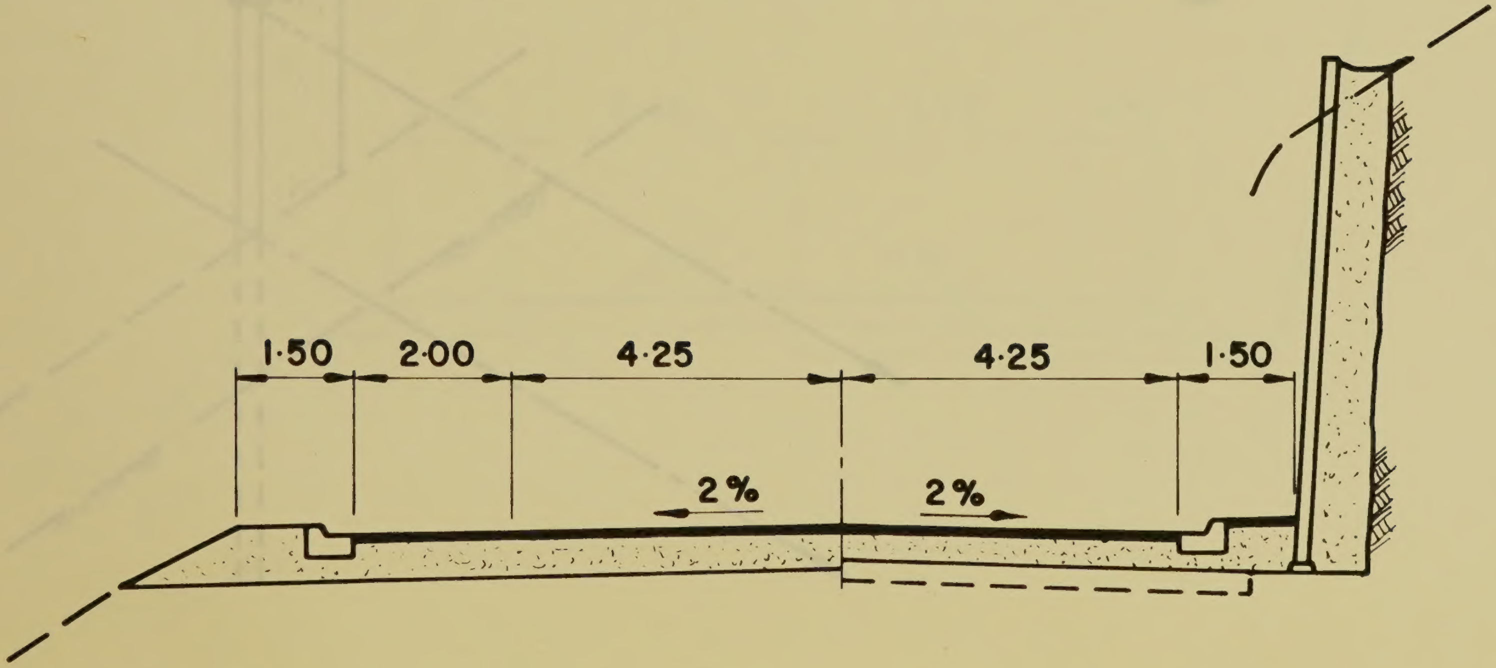
UPHILL WIDENING
IN ROCK CUT
(NO FACING)

PLATE 5


1·50
2·00
4·25
4·25
1·50
2%
2%

A3

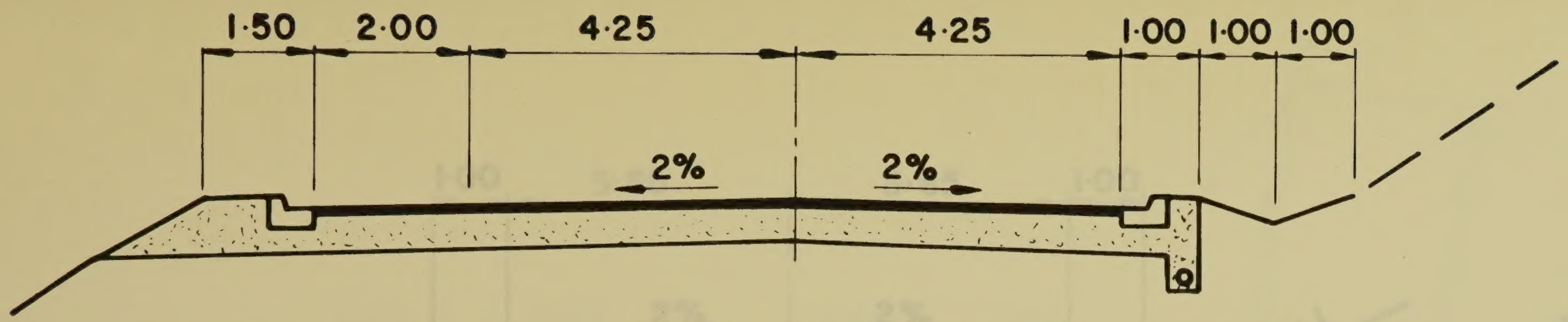
UPHILL WIDENING
IN EARTH CUT
(WITH BIN WALL)


1·50
2·00
4·25
4·25
1·50
2%
2%

A4

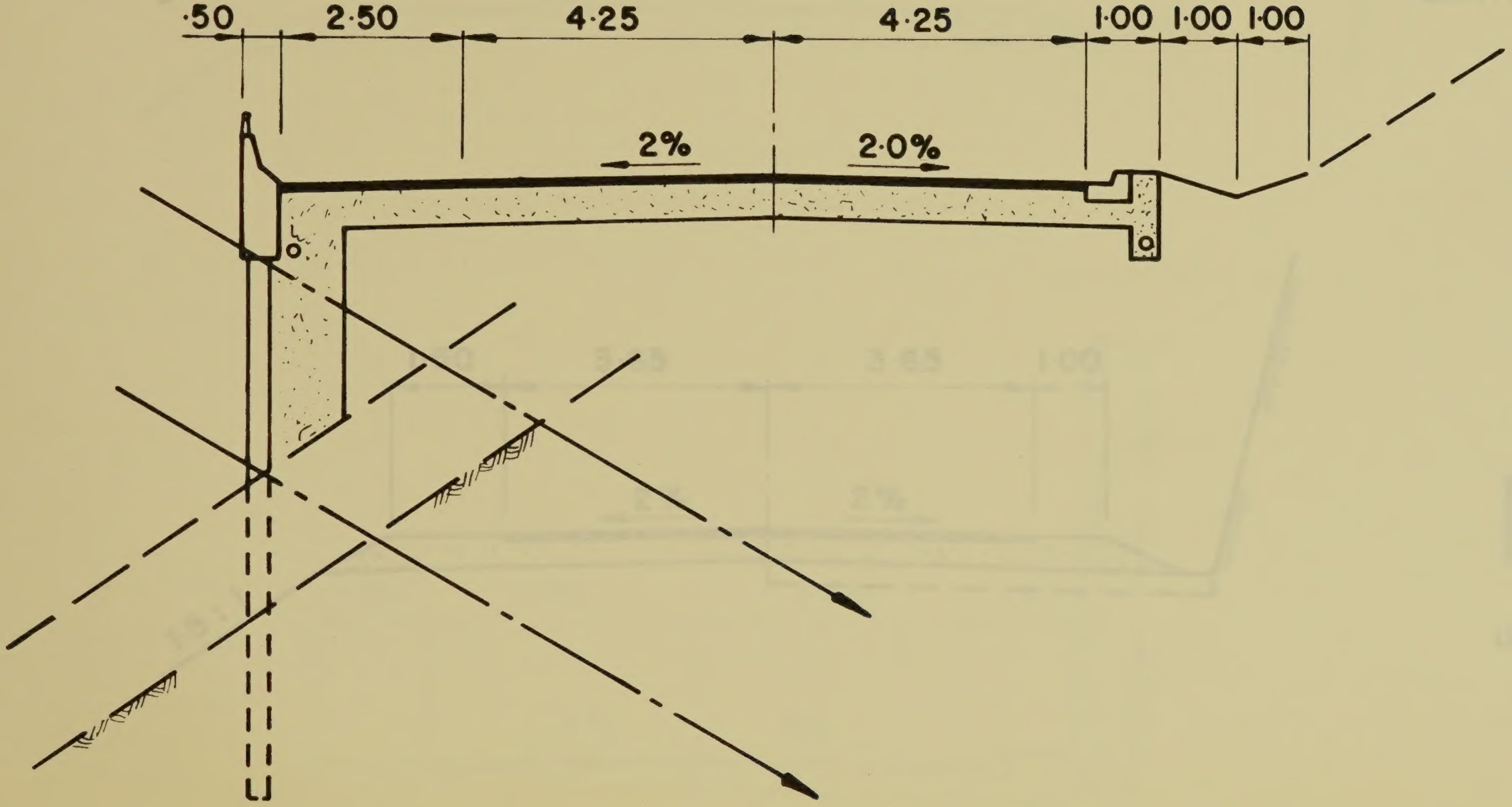
UPHILL WIDENING
IN ROCK CUT
(WITH STEEL FACING)

PLATE 6


1·50
2·00
4·25
4·25
1·00
1·00
1·00
2%
2%

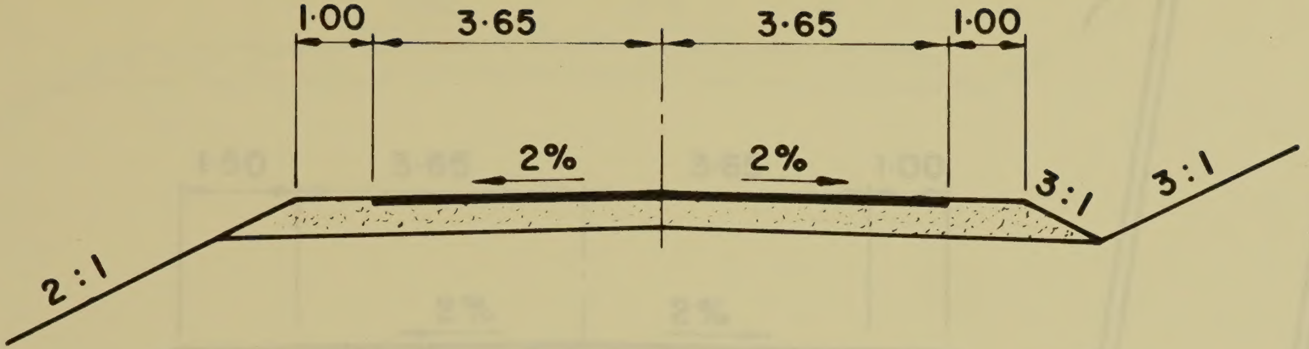
A5

DOWNHILL WIDENING
ON ROCK FILL


·50
2·50
4·25
4·25
1·00
1·00
1·00
2%
2·0%

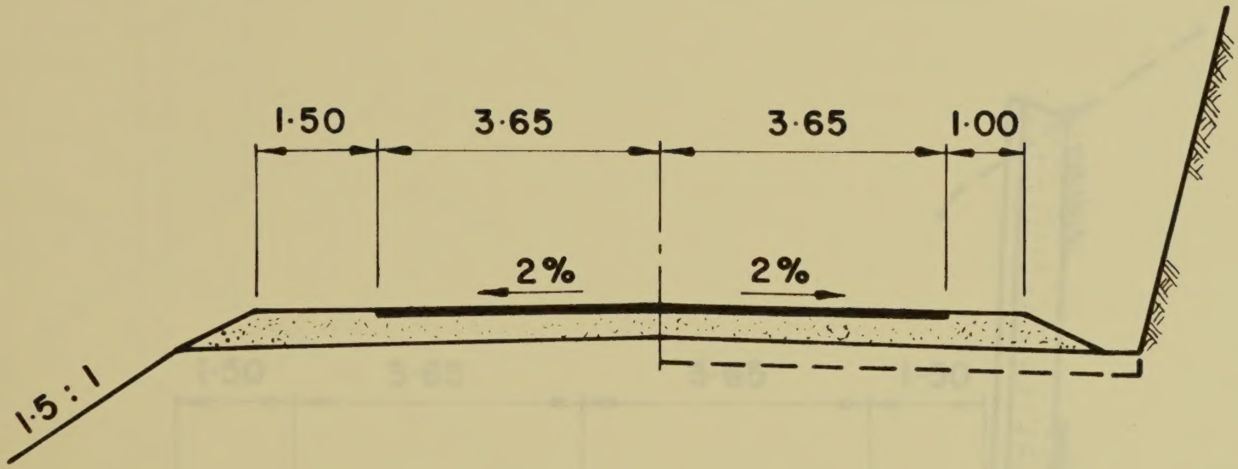
A6

DOWNHILL WIDENING
WITH TIEBACK
WALL SYSTEM


1·00
3·65
3·65
1·00
2%
2%
3:1
3:1
2:1

B1

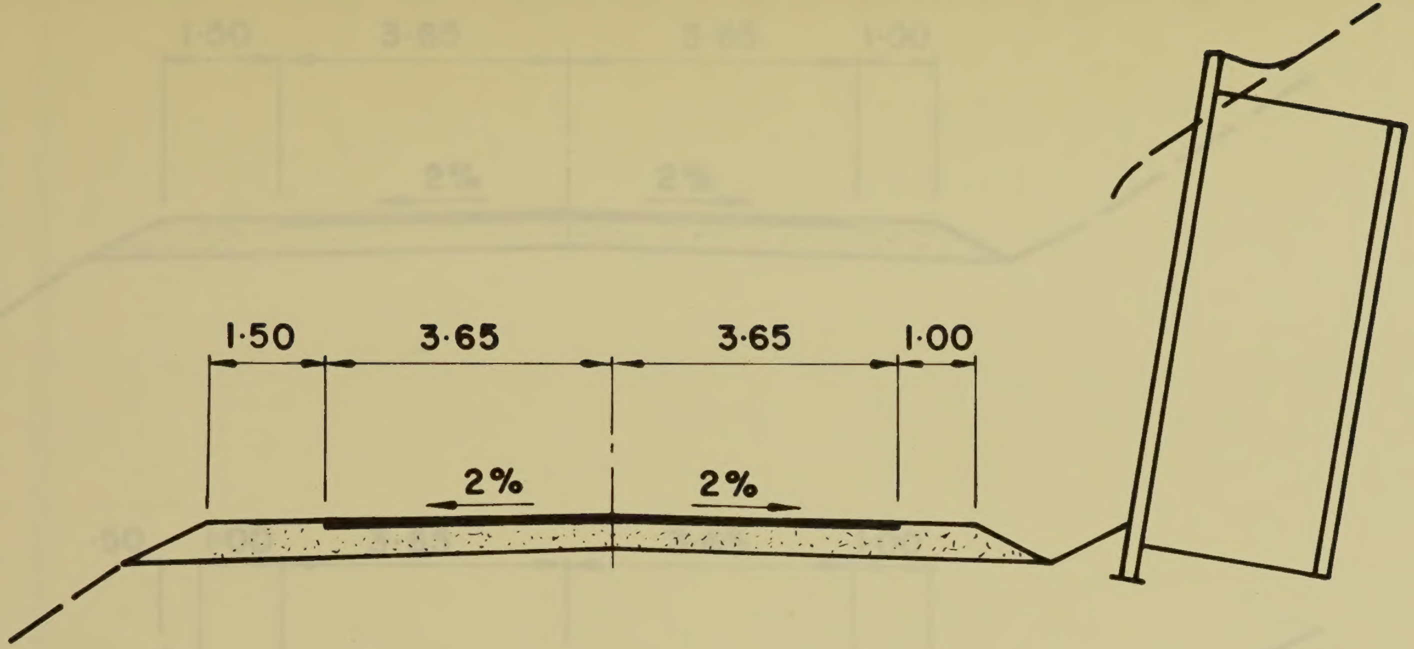
EARTH FILL / EARTH CUT


1·50
3·65
3·65
1·00
2%
2%
1·5:1

B2

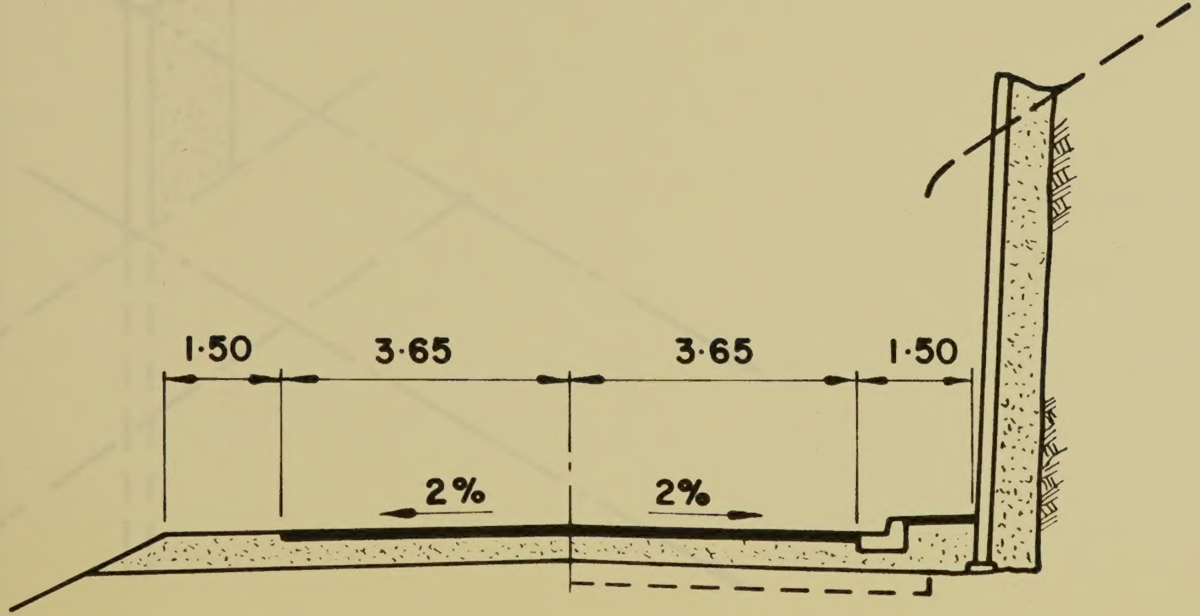
UPHILL WIDENING
IN ROCK CUT
(NO FACING)

PLATE 8


1·50
3·65
3·65
1·00
2%
2%

B3

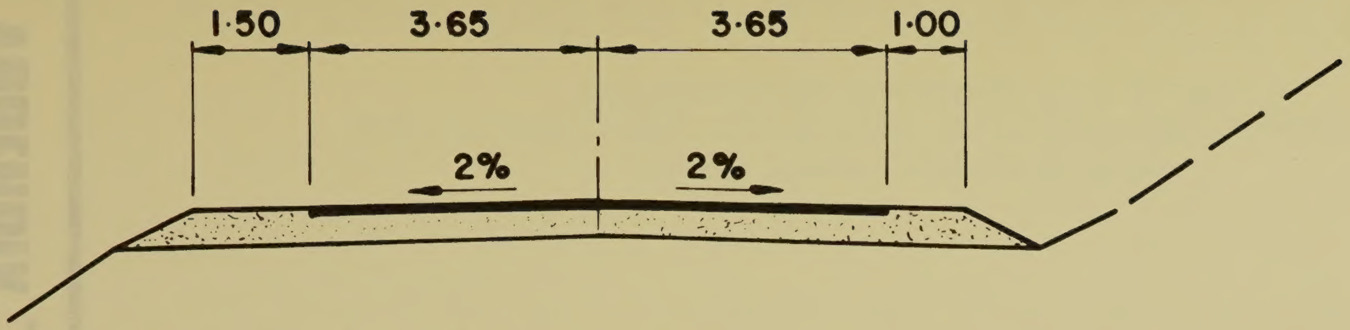
UPHILL WIDENING
IN EARTH CUT
(WITH BIN WALL)


1·50
3·65
3·65
1·50
2%
2%

B4

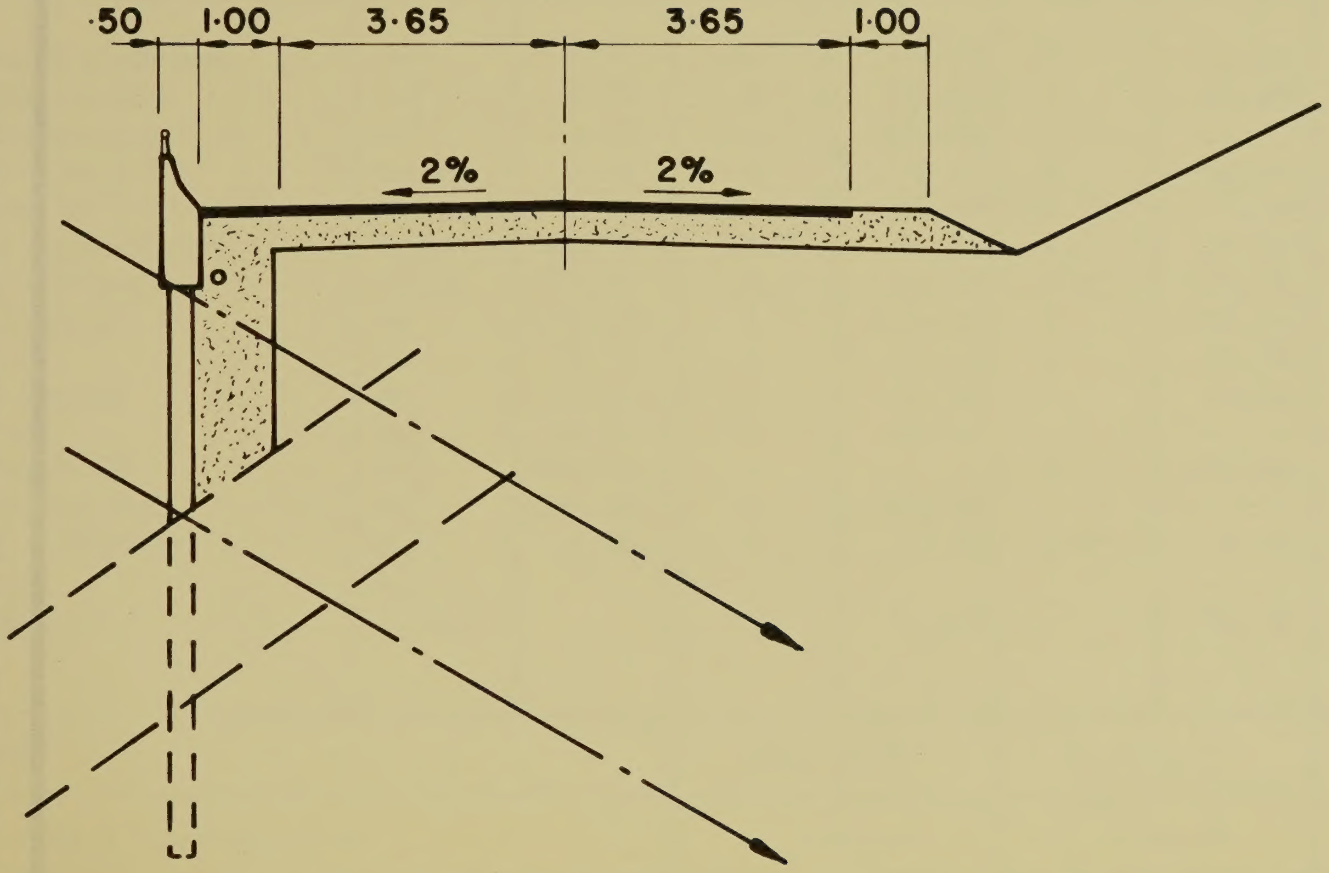
UPHILL WIDENING
IN ROCK CUT
(WITH STEEL FACING)

PLATE 9


1·50
3·65
3·65
1·00
2%
2%

B5

DOWNHILL WIDENING
ON ROCK FILL


·50
1·00
3·65
3·65
1·00
2%
2%

B6

DOWNHILL WIDENING
WITH TIEBACK
WALL SYSTEM

PLATE 10

APPENDIX 'D' UNIT CONSTRUCTION COSTS

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
FIFTY ROAD - SECTION 'A-A'

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A4)		Downhill (A6)		Uphill (B4)		Downhill (B6)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	12	9.00	10	7.50	8	6.00	6	4.50
2. Earth Excavation	m^3	4.00	8	32.00	4	16.00	8	32.00	3	12.00
3. Rock Excavation	m^3	15.00	24	360.00	-	-	10	150.00	-	-
4. Granular 'A' (150)	tonne	6.00	5	30.00	4	24.00	4	24.00	3.5	21.00
5. Granular 'B' (230-300)	tonne	5.00	16	80.00	14	70.00	12	60.00	10	50.00
6. Hot Mix Asphalt (90)	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.3	26.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.07	10.50
8. Storm Sewers	m	100.00	1	100.00	1	100.00	1	100.00	1	100.00
9. Subdrain	m	15.00	1	15.00	1	15.00	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	1	15.00	1	15.00	-	-
11. Guardrail	m	40.00	1	40.00	-	-	1	40.00	-	-
12. Retaining Wall	m^2	400.00	-	-	4	1,600.00	-	-	3	1,200.00
13. Steel Facing Wall	m^2	200.00	7	1,400.00	-	-	5	1,000.00	-	-
14. Topsoil & Sodding	m^2	3.00	4	12.00	2.5	7.50	4	12.00	2	6.00
15. Utilities	L.S.		-		-	-	-	-	-	-
16. Miscellaneous	L.S.			94.50		97.50		78.00		70.00
Sub Total			$2,250.00		$2,000.00		$1,550.00		$1,500.00	
Engineering & Contingencies			250.00		250.00		175.00		175.00	
Unit Cost/m			$2,500.00		$2,250.00		$1,725.00		$1,675.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
FIFTY ROAD - SECTION 'B-B'

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A4)		Downhill (A6)		Uphill (B4)		Downhill (B6)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	10	7.50	8	6.00	6	4.50	4	3.00
2. Earth Excavation	m^3	4.00	8	32.00	5	20.00	8	32.00	4	16.00
3. Rock Excavation	m^3	15.00	18	270.00	-	-	5	45.00	-	-
4. Granular 'A'	tonne	6.00	5	30.00	4	24.00	4	24.00	3.5	21.00
5. Granular 'B'	tonne	5.00	16	80.00	13	65.00	10	50.00	8	40.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.3	26.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.07	10.50
8. Storm Sewers	m	100.00	1	100.00	1	100.00	1	100.00	1	100.00
9. Subdrain	m	15.00	1	15.00	1	15.00	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	1	15.00	1	15.00	-	-
11. Guardrail	m	40.00	1	40.00	-	-	1	40.00	-	-
12. Retaining Wall	m^2	400.00	-	-	3.5	1,400.00	-	-	2.5	1,000.00
13. Steel Facing Wall	m^2	200.00	6	1,200.00	-	-	4	800.00	-	-
14. Topsoil & Sodding	m^2	3.00	4	12.00	2.5	7.50	3	9.00	2	6.00
15. Utilities	L.S.		-	-	-	-	-	-	-	-
16. Miscellaneous	L.S.			88.00		100.00		47.50		77.50
Sub Total			$1,950.00		$1,800.00		$1,200.00		$1,300.00	
Engineering & Contingencies			225.00		225.00		150.00		150.00	
Unit Cost/m			$2,175.00		$2,025.00		$1,350.00		$1,450.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
FIFTY ROAD - SECTION 'C-C'

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A3)		Downhill (A5)		Uphill (B3)		Downhill (B5)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	-	-	20	15.00	-	-	18	13.50
2. Earth Excavation	m^3	4.00	15	60.00	50	200.00	10	40.00	25	100.00
3. Rock Excavation	m^3	15.00	-	-	-	-	-	-	-	-
4. Granular 'A'	tonne	6.00	5	30.00	5	30.00	4	24.00	4	24.00
5. Granular 'B'	tonne	5.00	10	50.00	10	50.00	8	40.00	8	40.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.2	24.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.06	9.00
8. Storm Sewers	m	100.00	1	100.00	1	100.00	-	-	-	-
9. Subdrain	m	15.00	-	-	-	-	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	2	30.00	-	-	-	-
11. Guardrail	m	40.00	1	40.00	1	40.00	1	40.00	1	40.00
12. Retaining Wall	m^2	400.00	-	-	-	-	-	-	-	-
13. Steel Facing Wall	m^2	200.00	1	200.00	-	-	1	200.00	-	-
14. Topsoil & Sodding	m^2	3.00	6	18.00	15	45.00	4	12.00	15	45.00
15. Utilities	L.S.			10.00		-		10.00		-
16. Miscellaneous	L.S.			39.50		42.50		26.00		26.00
Sub Total			$625.00		$600.00		$425.00		$325.00	
Engineering & Contingencies			75.00		75.00		50.00		50.00	
Unit Cost/m			$700.00		$675.00		$475.00		$375.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
FIFTY ROAD - SECTION 'D-D'

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A3)		Downhill (A5)		Uphill (B3)		Downhill (B5)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	10	7.50	24	18.00	8	6.00	14	10.50
2. Earth Excavation	m^3	4.00	16	64.00	30	120.00	7	28.00	15	60.00
3. Rock Excavation	m^3	15.00	-	-	-	-	-	-	-	-
4. Granular 'A'	tonne	6.00	5	30.00	5	30.00	4	24.00	4	24.00
5. Granular 'B'	tonne	5.00	10	50.00	10	50.00	8	40.00	8	10.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.2	24.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.06	9.00
8. Storm Sewers	m	100.00	1	100.00	1	100.00	-	-	-	-
9. Subdrain	m	15.00	-	-	-	-	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	2	30.00	-	-	-	-
11. Guardrail	m	40.00	1	40.00	1	10.00	1	40.00	1	40.00
12. Retaining Wall	m^2	400.00	-	-	-	-	-	-	-	-
13. Steel Facing Wall	m^2	200.00	3	600.00	-	-	1.5	300.00	-	-
14. Topsoil & Sodding	m^2	3.00	6	18.00	20	60.00	5	15.00	14	42.00
15. Utilities	L.S.			10.00	-	-		10.00		-
16. Miscellaneous	L.S.			53.00		29.50		29.00		25.50
Sub Total			$1,050.00		$525.00		$525.00		$275.00	
Engineering & Contingencies			125.00		50.00		50.00		50.00	
Unit Cost/m			$1,175.00		$575.00		$575.00		$325.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
FIFTY ROAD - SECTION 'E-E'

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			A1				B1			
			Quantity	Total			Quantity	Total		
1. Clearing & Grubbing	m^2	0.75	-	-			-	-		
2. Earth Excavation	m^3	4.00	10	40.00			6	24.00		
3. Rock Excavation	m^3	15.00	-	-			-	-		
4. Granular 'A'	tonne	6.00	4	24.00			3.5	21.00		
5. Granular 'B'	tonne	5.00	10	50.00			6	30.00		
6. Hot Mix Asphalt	tonne	20.00	1.4	28.00			1.2	24.00		
7. Asphalt Cement	tonne	150.00	0.08	12.00			0.06	9.00		
8. Storm Sewers	m	100.00	-	-			-	-		
9. Subdrain	m	15.00	-	-			-	-		
10. Curb & Gutter	m	15.00	-	-			-	-		
11. Guardrail	m	40.00	-	-			-	-		
12. Retaining Wall	m^2	400.00	-	-			-	-		
13. Steel Facing Wall	m^2	200.00	-	-			-	-		
14. Topsoil & Sodding	m^2	3.00	8	24.00			6	18.00		
15. Utilities	L.S.			15.00				15.00		
16. Miscellaneous	L.S.			7.00				9.00		
Sub Total			$200.00				$150.00			
Engineering & Contingencies			25.00				25.00			
Unit Cost/m			$225.00				$175.00			

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
FIFTY ROAD - SECTION 'F-F'

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			A2				B2			
			Quantity	Total			Quantity	Total		
1. Clearing & Grubbing	m^2	0.75	28	21.00			22	16.50		
2. Earth Excavation	m^3	4.00	40	160.00			30	12.00		
3. Rock Excavation	m^3	15.00	54	810.00			36	540.00		
4. Granular 'A'	tonne	6.00	7	42.00			4	24.00		
5. Granular 'B'	tonne	5.00	10	50.00			8	40.00		
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00			1.2	24.00		
7. Asphalt Cement	tonne	150.00	0.09	13.50			0.06	9.00		
8. Storm Sewers	m	100.00	1	100.00			-	-		
9. Subdrain	m	15.00	-	-			-	-		
10. Curb & Gutter	m	15.00	2	30.00			-	-		
11. Guardrail	m	40.00	-	-			-	-		
12. Retaining Wall	m^2	400.00	-	-			-	-		
13. Steel Facing Wall	m^2	200.00	-	-			-	-		
14. Topsoil & Sodding	m^2	3.00	-	-			-	-		
15. Utilities	L.S.		-	-			-	-		
16. Miscellaneous	L.S.			39.50				34.50		
Sub Total			$1,300.00				$700.00			
Engineering & Contingencies			150.00				75.00			
Unit Cost/m			$1,450.00				$775.00			

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
DEWITT ROAD - STATION 1+07 (3+50)

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A4)		Downhill (A6)		Uphill (B4)		Downhill (B6)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	-	-	-	-	-	-	-	-
2. Earth Excavation	m^3	4.00	3	12.00	26	104.00	3	12.00	12	48.00
3. Rock Excavation	m^3	15.00	45	675.00	-	-	25	375.00	-	-
4. Granular 'A'	tonne	6.00	5	30.00	4	24.00	4	24.00	3.5	21.00
5. Granular 'B'	tonne	5.00	21	105.00	20	100.00	15	75.00	13	65.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.3	26.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.07	10.50
8. Storm Sewers	m	100.00	1	100.00	1	100.00	1	100.00	1	100.00
9. Subdrain	m	15.00	1	15.00	1	15.00	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	1	15.00	1	15.00	-	-
11. Guardrail	m	40.00	1	40.00	-	-	1	40.00	-	-
12. Retaining Wall	m^2	400.00	-	-	7.5	3,000.00	-	-	5.25	2,100.00
13. Steel Facing Wall	m^2	200.00	8.5	1,700.00	-	-	6	1,200.00	-	-
14. Topsoil & Sodding	m^2	3.00	4	12.00	2	6.00	4	12.00	2	6.00
15. Utilities	L.S.		-	-	-		-	-	-	-
16. Miscellaneous	L.S.			133.50		188.50		114.00		123.50
Sub Total			$2,900.00		$3,600.00		$2,000.00		$2,500.00	
Engineering & Contingencies			300.00		300.00		250.00		250.00	
Unit Cost/m			$3,200.00		$3,900.00		$2,250.00		$2,750.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
DEWITT ROAD - STATION 1+22 (4+00)

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A4)		Downhill (A6)		Uphill (B4)		Downhill (B6)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	-	-	-	-	-	-	-	-
2. Earth Excavation	m^3	4.00	3	12.00	30	120.00	3	12.00	11	44.00
3. Rock Excavation	m^3	15.00	50	750.00	-	-	26	390.00	-	-
4. Granular 'A'	tonne	6.00	5	30.00	4	24.00	4	24.00	3.5	21.00
5. Granular 'B'	tonne	5.00	22	110.00	21	105.00	16	80.00	14	70.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.3	26.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.07	10.50
8. Storm Sewers	m	100.00	1	100.00	1	100.00	1	100.00	1	100.00
9. Subdrain	m	15.00	1	15.00	1	15.00	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	1	15.00	1	15.00	-	-
11. Guardrail	m	40.00	1	40.00	-	-	1	40.00	-	-
12. Retaining Wall	m^2	400.00	-	-	8	3,200.00	-	-	5.5	2,200.00
13. Steel Facing Wall	m^2	200.00	9.5	1,900.00	-	-	7	1,400.00	-	-
14. Topsoil & Sodding	m^2	3.00	4	12.00	2	6.00	4	12.00	2	6.00
15. Utilities	L.S.		-	-	-	-	-	-	-	-
16. Miscellaneous	L.S.			153.50		167.50		97.00		122.50
Sub Total			$3,200.00		$3,800.00		$2,200.00		$2,600.00	
Engineering & Contingencies			300.00		300.00		250.00		250.00	
Unit Cost/m			$3,500.00		$4,100.00		$2,450.00		$2,850.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
DEWITT ROAD - STATION 1+37 (4+50)

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A4)		Downhill (A6)		Uphill (B4)		Downhill (B6)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	-	-	-	-	-	-	-	-
2. Earth Excavation	m^3	4.00	4	16.00	20	80.00	4	16.00	8	32.00
3. Rock Excavation	m^3	15.00	40	600.00	-	-	16	240.00	-	-
4. Granular 'A'	tonne	6.00	5	30.00	4	24.00	4	24.00	3.5	21.00
5. Granular 'B'	tonne	5.00	18	90.00	17	85.00	13	65.00	10	50.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.3	26.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.07	10.50
8. Storm Sewers	m	100.00	1	100.00	1	100.00	1	100.00	1	100.00
9. Subdrain	m	15.00	1	15.00	1	15.00	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	1	15.00	1	15.00	-	-
11. Guardrail	m	40.00	1	40.00	-	-	1	40.00	-	-
12. Retaining Wall	m^2	400.00	-	-	6.5	2,600.00	-	-	4.0	1,600.00
13. Steel Facing Wall	m^2	200.00	8	1,600.00	-	-	4.5	900.00		
14. Topsoil & Sodding	m^2	3.00	4	12.00	2	6.00	4	12.00	2	6.00
15. Utilities	L.S.		-	-	-	-	-	-	-	-
16. Miscellaneous	L.S.			119.50		127.50		105.00		104.50
Sub Total			$2,700.00		$3,100.00		$1,550.00		$1,950.00	
Engineering & Contingencies			300.00		300.00		250.00		250.00	
Unit Cost/m			$3,000.00		$3,400.00		$1,800.00		$2,200.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
DEWITT ROAD - STATION 1+51 (4+95)

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A4)		Downhill (A6)		Uphill (B4)		Downhill (B6)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	-	-	-	-	-	-	-	-
2. Earth Excavation	m^3	4.00	4	16.00	16	64.00	4.00	16.00	7	28.00
3. Rock Excavation	m^3	15.00	42	630.00	-	-	18	270.00	-	-
4. Granular 'A'	tonne	6.00	5	30.00	4	24.00	4	24.00	3.5	21.00
5. Granular 'B'	tonne	5.00	19	95.00	16	80.00	12	60.00	9	45.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.3	26.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.07	10.50
8. Storm Sewers	m	100.00	1	100.00	1	100.00	1	100.00	1	100.00
9. Subdrain	m	15.00	1	15.00	1	15.00	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	1	15.00	1	15.00	-	-
11. Guardrail	m	40.00	1	40.00	-	-	1	40.00	-	-
12. Retaining Wall	m^2	400.00	-	-	5	2,000.00	-	-	3.5	1,400.00
13. Steel Facing Wall	m^2	200.00	8.5	1,700.00	-	-	5	1,000.00	-	-
14. Topsoil & Sodding	m^2	3.00	4	12.00	2	6.00	4	12.00	2	6.00
15. Utilities	L.S.			-	-	-	-	-	-	-
16. Miscellaneous	L.S.			134.50		98.50		80.00		63.50
Sub Total			$2,850.00		$2,450.00		$1,650.00		$1,700.00	
Engineering & Contingencies			300.00		300.00		250.00		250.00	
Unit Cost/m			$3,150.00		$2,750.00		$1,900.00		$1.950.00	

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - SIDE HILL RECONSTRUCTION
DEWITT ROAD - STATION 1+68 (5+50)

Item	Unit	Unit Price	Without Fruitland				With Fruitland			
			Uphill (A4)		Downhill (A6)		Uphill (B4)		Downhill (B6)	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1. Clearing & Grubbing	m^2	0.75	-	-	-	-	-	-	-	-
2. Earth Excavation	m^3	4.00	4	16.00	16	64.00	4	16.00	10	40.00
3. Rock Excavation	m^3	15.00	36	540.00	-	-	11	165.00	-	-
4. Granular 'A'	tonne	6.00	5	30.00	4	24.00	4	24.00	3.5	21.00
5. Granular 'B'	tonne	5.00	18	90.00	16	80.00	11	55.00	10	50.00
6. Hot Mix Asphalt	tonne	20.00	1.7	34.00	1.7	34.00	1.2	24.00	1.3	26.00
7. Asphalt Cement	tonne	150.00	0.09	13.50	0.09	13.50	0.06	9.00	0.07	10.50
8. Storm Sewers	m	100.00	1	100.00	1	100.00	1	100.00	1	100.00
9. Subdrain	m	15.00	1	15.00	1	15.00	-	-	-	-
10. Curb & Gutter	m	15.00	2	30.00	1	15.00	1	15.00	-	-
11. Guardrail	m	40.00	1	40.00	-	-	1	40.00	-	-
12. Retaining Wall	m^2	400.00	-	-	5.5	2,200.00	-	-	3.75	1,500.00
13. Steel Facing Wall	m^2	200.00	6.75	1,350.00	-	-	3.75	750.00	-	-
14. Topsoil & Sodding	m^2	3.00	4	12.00	2	6.00	4	12.00	2	6.00
15. Utilities	L.S.		-	-	-	-	-	-	-	-
16. Miscellaneous	L.S.			129.50		148.50		90.00		96.50
Sub Total			$2,400.00		$2,700.00		$1,300.00		$1,850.00	
Engineering & Contingencies			300.00		300.00		250.00		250.00	
Unit Cost/m			$2,700.00		$3,000.00		$1,550.00		$2,100.00	

APPENDIX `E´ PRELIMINARY COST ESTIMATES

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - FIFTY ROAD
HIGHWAY 8 TO RIDGE ROAD

STANDARD	LIMITS	SECTION	UNIT PRICE	LENGTH	SUB-TOTAL
'A'	King Street to Escarpment	A1	225	970	$ 218,250
	Escarpment Sections	A1	225	180	40,500
		A2	1,500	200	300,000
		A3	1,000	310	310,000
		A4/A6	2,250	240	540,000
	Escarpment to Ridge Road	A1	225	400	90,000
	Rounding				1,250
TOTAL				2,300	$1,500,000
'B'	King Street to Excarpment	B1	175	970	169,750
	Escarpment Sections	B1	175	180	31,500
		B2	750	200	150,000
		B3	500	310	155,000
		B4/B6	1,500	240	360,000
	Escarpment to Ridge Road	B1	175	400	70,000
	Rounding				13,750
TOTAL				2,300	$ 950,000

EXCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - McNEILLY ROAD
HIGHWAY 8 TO RIDGE ROAD

STANDARD	LIMITS	SECTION	UNIT PRICE	LENGTH	SUB-TOTAL
'A'	King Street to Escarpment	A1	225	400	$ 90,000
	Escarpment Sections	A1	225		
		A2	1,500	90	135,000
		A3	1,000	260	260,000
		A4/A6	2,250	330	742,500
	Escarpment to Ridge Road	A1	225	500	112,500
	Rounding				10,000
TOTAL				1,580	$1,350,000
'B'	King Street to Escarpment	B1	175	400	70,000
	Escarpment Sections	B1	175		
		B2	750	90	67,500
		B3	500	260	130,000
		B4/B6	1,500	330	495,000
	Escarpment to Ridge Road	B1	175	500	87,500
	Rounding				1,000
TOTAL				1,580	$ 850,000

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - DEWITT ROAD
HILTS LANE TO RIDGE ROAD

STANDARD	LIMITS	SECTION	UNIT PRICE	LENGTH	SUB-TOTAL
'A'	Escarpment Sections	A1	225		$
		A2	1,500		
		A3	1,000	240	240,000
		A4/A6	3,000	275	825,000
	Escarpment to Ridge Road	A1	225	50	11,250
	Ridge Road	A1	225	600	135,000
	Crossing Protection				15,000
	Rounding				23,750
TOTAL				1,165	$1,250,000
'B'	Escarpment Sections	B1	175		
		B2	750		
		B3	500	240	120,000
		B4/B6	2,000	275	550,000
	Escarpment to Ridge Road	B1	175	50	8,750
	Ridge Road	B1	225	600	135,000
	Crossing Protection				15,000
	Rounding				21,250
TOTAL				1,165	$ 850,000

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - NEW MOUNTAIN ROAD
KING STREET TO RIDGE ROAD

STANDARD	LIMITS	SECTION	UNIT PRICE	LENGTH	SUB-TOTAL
	King Street to Escarpment	A1	225	330	$ 74,250
	Escarpment Sections	A1	225		
		A2	1,500		
		A3	1,000	400	400,000
'A'		A4/A6	2,250	250	562,500
	Escarpment to Ridge Road	A1	225	80	18,000
	Ridge Road	A1	225	600	135,000
	T.H. & B. Structure				500,000
	Rounding				10,250
TOTAL				1,060	$1,700,000
	King Street to Escarpment	B1	175	330	57,750
	Escarpment Sections	B1	175		
		B2	750		
		B3	500	400	200,000
'B'		B4/B6	1,500	250	375,000
	Escarpment to Ridge Road	B1	175	80	14,000
	Ridge Road	B1	225	600	135,000
	T.H. & B. Structure				500,000
	Rounding				18,250
TOTAL				1,060	$1,300,000

ESCARPMENT ACCESSIBILITY STUDY
PRELIMINARY COST ESTIMATE - FRUITLAND ROAD
HIGHWAY 8 TO RIDGE ROAD

	Item	Unit	Unit Price	Initial Development (3)		Ultimate Development (5)	
				Quantity	Total	Quantity	Total
1.	Clearing & Grubbing	m^2	0.75	24,000	18,000	12,000	9,000
2.	Earth Excavation	m^3	3.00	25,000	75,000	30,000	90,000
3.	Earth Borrow	m^3	3.50	120,000	420,000	4,000	14,000
4.	Rock Excavation	m^3	10.00	58,000	580,000	30,000	300,000
5.	Granular 'A'	tonne	6.00	18,000	108,000	13,000	78,000
6.	Granular 'B'	tonne	5.00	32,000	160,000	24,000	120,000
7.	Hot Mix Asphalt	tonne	20.00	8,500	170,000	6,000	120,000
8.	Asphalt Cement	tonne	150.00	460	69,000	320	48,000
9.	Storm Sewers	L.S.			156,000		60,000
10.	Curb & Gutter	m	15.00	3,600	54,000	3,600	54,000
11.	Guardrail	m	40.00	1,650	66,000	1,750	70,000
12.	Topsoil & Sodding	L.S.			30,000		30,000
13.	Road Relocations	L.S.			100,000		150,000
14.	Steel Facing Wall	m^2	200.00		-		-
15.	Overhead Structure	L.S.			1,500,000		950,000
16.	Ridge Road Underpass	L.S.			-		400,000
17.	Utilities	L.S.			30,000		15,000
18.	Miscellaneous	L.S.			170,000		132,000
	Sub-Total				$3,600,000		$2,650,000
	Engineering & Contingencies				400,000		250,000
	Total Estimated Cost (excluding property)				$4,000,000		$2,900,000

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